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Pyke

Report on the legibility of type.

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*Special Report Series, No. 110.*

Privy Council

# MEDICAL RESEARCH COUNCIL

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## REPORT ON THE LEGIBILITY OF PRINT

BY

R. L. PYKE, M.A.

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
1926

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# PREFACE

The Committee appointed by the Treasury, at the instance of H.M. Stationery Office, 'to select the best faces of Type and Modes of Display for Government Printing' suggested in their report, published in 1922, that the Medical Research Council should be approached with a view to the inception of inquiries upon physiological and psychological lines into the legibility of printed matter and the optical properties of paper and ink. Upon the consequent request of the Stationery Office, the Council in 1923 appointed a Committee, the composition of which is given opposite, to organize and direct research work into the subject.

This Committee upon the Legibility of Type framed a scheme of investigation, of which part was entrusted to Mr. R. L. Pyke, working in the Psychological Laboratory, University of Cambridge, under the direction of Mr. F. C. Bartlett. The account of Mr. Pyke's experimental work forms the subject of the Report now issued, and with it is given a detailed analysis of previous investigations of the same kind.

The Committee are aware that the new results now published cover only a small part of the whole field to be explored; for example, no attempt has been made to assess the relative legibility of the different styles of figures used on the dials of clocks or scientific instruments, or in mathematical and statistical tables. Nevertheless, they do not think that it is advisable to continue the work on the same lines at the present time. As a result of their experience, they have formed the opinion that the experimental methods now available are not likely to provide clear and direct answers to the many practical problems remaining to be solved, and that the whole subject can more profitably be approached by subordinating it as part of a more general and comprehensive scheme of research into the physiology of vision. Another Committee has been appointed by the Medical Research Council to direct such a wider scheme, and the Committee upon the Legibility of Type are of opinion that further work on this subject should be carried out under the supervision of that body. This advice has been adopted by the Council, who would take this opportunity of expressing their thanks to the Committee and to the investigators for the work they have already done—work now being continued with wider scope.

30*th September*, 1926.

Medical Research Council,
15 York Buildings, Adelphi,
London, W.C.2.

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# THE LEGIBILITY OF PRINT

By R. L. Pyke, M.A.

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## I. INTRODUCTION

### 1. Neglect of the Problem

It may seem strange that in its early history the practice and, later, the study of the legibility of print should have been so neglected. Three influences are responsible, namely the aesthetics of printing, its technology, and its economics. Until the late eighteenth century it was the aesthetic aspect with which printers were most deeply concerned. Although they often achieved legibility, they thought of it fundamentally in terms of aesthetic appearance. With the development of metallurgy and of steam and electrical power during the nineteenth century, interest was diverted to the improvement of composing and printing machinery, for which the scope was so vast that the technical aspect became predominant.

But prodigious mechanical intricacy was followed in the printing industry, as in most others, by sudden and violent aggravations of economic problems (some old, some new), which tended to find their solutions according to the relative power of masters or men. A single example from present times illustrates the importance of such influences. Legros and Grant say: 'In Great Britain compositors

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are paid by the thousand ens, but the scale of payment is increased with reduction in body size [owing to the greater difficulty of handling smaller founts]. The effect of this is to discourage the use of extended faces.' This is not to say that modern printers have failed ever to use legible types, but they seem content very largely to follow tradition. The owners of private presses, however, who, if not less, are affected differently by the pressure of commercial exigencies, positively exalt tradition, which seems to bound their conceptions of future typographical reform by needlessly narrow limits. Both these interested classes, the aestheticians and the technicians, perpetually paid lip-service to the importance of legibility, and admittedly often made concrete suggestions. But they were always really dominated, the former by ideas about grace of line and artistic unity of page, the latter by the economics of their industry, their own enormous technical difficulties, and the others' artistic ideas, which have come to be their orthodox tribute to the aesthetic aspect's importance. In these ways attention has been diverted from legibility proper to decorative effect and mechanical excellence.

## 2. Significance of the Present Work

It is very difficult to carry out research into the legibility of type without in various ways falsifying the genuine problems involved, and there is very little previous co-ordinated, strictly relevant research. Mistakes have been made during the present research, and results little more than negative sometimes obtained ; but these failures are purposely recorded, and in their record the chief value of this work may lie. Indeed, a very important reason for, if not the principal explanation of, the lack of consistent and substantial results able to command wide and practical respect may reside in the fact that the difficulties, both simple and subtle, have been grossly underestimated ; that what was only a part of the problem has sometimes been taken for the whole ; and that either the technique or the underlying principles of experiments have been repeatedly open to criticism. These obstacles must be overcome, and more attention devoted to evolving an experimental technique free from the two main blemishes of the past. These have been, first, that data are unwittingly altered between the beginning and end of an inquiry to suit the technique, and, secondly, a tendency to abandon realistic problems in favour of artificial ones to which the experimental conditions themselves ensure in advance a particular solution. Only when a suitable technique has been developed shall we be in a position to assert either that no such thing as objective legibility exists, or that some one type-face or typographical property is superior to others.

The principal aim of the present work then is twofold. On the one hand, it is an endeavour to bring to a focus in the present the theories and researches of the past. For the greater part these have shown inadequate reference to one another or to any common basis. On the other hand, the attempt is made to approach the main problem not merely in new ways, but *in the light of this past work.* For this account to constitute any advance, however, the procedure

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and numerous experimental difficulties must be described in detail. Many past writers, while stressing the importance of legibility in general terms, and offering *a priori* views or remedies in respect of many of its problems, failed to expose the actual difficulties and imperfections which were bound to detract from the value of whatever results they might obtain, and this failure has retarded progress.

## II. PREVIOUS WORK

### 1. Its Relation to Physiology and Psychology

It is rather unfortunate that the legibility of printed letters has offered so suitable a field to psychologists and physiologists for testing theories which had primary reference to other problems. Writers, whose essential problem was in psychology, say, memory or apperception, or in physiology, visual acuity or peripheral vision, have often been embarrassingly willing to make passing suggestions about the objective relative legibility of letters or types—problems which they believed they had, incidentally, partially solved. Some of these incomplete or apparent discoveries would then reach the notice of printers or other mainly commercial bodies. Apparently typographical changes did not, as a rule, follow, but the assertions made have often been quoted as possessing the full authority of Science. No genuine solution of our problem, it goes without saying, can ever be reached without the most understanding reference to both physiology and psychology, but the legibility of print must then be the central problem. It would be hazardous indeed for an investigator into legibility to propose, without further change, so to speak, of his centre of operations, or investigations of any other sort, to offer what could have been for him no more than suggestive side-issues as discoveries in their own spheres to either of those sciences.

Four main fields of study comprise the entire scope of research. Each lends itself to division into sub-topics, in each of which the work has been done mostly by different classes of persons, although several classes have worked in more than one subject. A comprehensive scheme of classification of these different aspects may best be presented in the form on the opposite page.

### 2. Analysis of its Results

It will be well at this point to survey *in extenso* the scientific and practical work upon legibility proper. This is not proposed for the history of the physiology and psychology of reading, because excellent critical reviews on these subjects, some quite up-to-date, are to be found in a number of books, monographs, &c. (see e. g. in the Table of References; Schwender, Huey, Schmidt, Gray, W. S. Smith, &c.). On the other hand, while several brief general accounts and detailed reviews of the literature on special questions of typographical reform have been written, there has not appeared to my knowledge any historical analysis, at once detailed and comprehensive, within the compass of a single work.

I have divided my subject into eighteen sub-topics, so as to cover the whole field. These sub-topics are given on the right hand side

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| Column 1. | | Column 2. | Column 3. | | | Column 4. |
|---|---|---|---|---|---|---|
| *The Physiology of Reading.* | | *The Psychology of Reading.* | *The influence of various typographical factors upon legibility.* | | | *The influence of various typographical factors on the aesthetic appearance of printed matter.* |
| *Medical.* | *Experimental.* | | | | | |
| 1. Eye-hygiene (in schools). | 1. Eye-movements and reading pauses. | 1. Fields of attention and distinct vision. | 1. Contrast. | 1. Contrast. | 1. Contrast of thickness and thinness. | 1. Unity of page. |
| 2. Pathological eyes. | 2. Ocular fatigue and accommodation. | 2. Perceptual processes. | 2. Faces of type. | 2. Faces of type. | 2. Criterion of legibility. | 2. Grace of line. |
| *Work by :* Ophthalmologists, doctors. | 3. Illumination. | 3. Reading units. | 3. Indentation. | 3. Indentation. | 3. Definition of legibility. | 3. Appropriateness of type-face. |
| | 4. Visual acuity tests. | 4. Reading rate. | 4. Leading. | 4. Leading. | 4. Faces of type. | 4. Uniformity of 'colour'. |
| | *Work by :* Experimental psychologists, physiologists. | *Work by :* Experimental psychologists. | 5. Length of line. | 5. Length of line. | 5. Illumination. | *Work by :* Printers, artists, owners of private presses, and experimental psychologists. |
| | | | 6. Margin. | 6. Margin. | 6. Indentation. | |
| | | | 7. Paper and ink. | 7. Paper and ink. | 7. Leading. | |
| | | | 8. Serifs. | 8. Size of type. | 8. Legibility of letters. | |
| | | | 9. Size of type. | 9. Thickness of limbs. | 9. Length of line. | |
| | | | 10. Spacing. | *Work by :* Other commercial interests, viz. : advertisers, and producers of catalogues, directories, and time-tables. | 10. Margin. | |
| | | | 11. Thickness of limbs. | | 11. Paper and ink. | |
| | | | *Work by :* Printers. | | 12. Projectors. | |
| | | | | | 13. Punctuation. | |
| | | | | | 14. Serifs. | |
| | | | | | 15. Size of type. | |
| | | | | | 16. Spacing. | |
| | | | | | 17. 'The Ideal Type.' | |
| | | | | | 18. Thickness of limbs. | |
| | | | | | *Work by :* Scientists. | |

of column 3, page 9. It will be convenient to take the headings, as there, alphabetically.[1] *Résumés*, in tabular form, of all work believed to have been published on these subjects (with very few exceptions of unobtainable articles) have been made; these *résumés* give chronologically in separate columns the author's name and year, his judgement, whether *a priori* or experimental, criterion of judgement, and experimental basis. All are printed in full in Appendix 1 *b*, with an index to these authors and the topics on which each has pronounced in Appendix 1 *c*.

This method of presentation has been adopted because it reveals, in my opinion, more succinctly than any other the lack of *practical* reference by successive writers to the investigations of their predecessors, and how it may be the diversity of experimental conditions and criteria which is responsible for the amazing contradictions that occur.

The reader may question the value of some of the pronouncements and of mere qualitative generalizations. These, however, are purposely included. They show how few convincing quantitative judgements have been produced by scientific methods of roughly the last thirty years as compared with various empirical efforts of the preceding seventy. Nor do names figure as largely in this section as they might, for the positions and achievements of particular writers can be seen from the *résumés*. What follows now is both a summary and an analysis of all these pronouncements, topic by topic. Discussion, however, of many of the problems raised is postponed to Section III.

1. '*Contrast*' *in thickness and thinness* (i. e. as opposed to uniform thickness of limb) (10 writers in 100 years : 1825–1924).

Only one writer is directly opposed to all contrast, and that on aesthetic grounds. One experimental psychologist would dispense with it, though he does not say why, and two others remain neutral. Two ophthalmologists give definite arguments in favour, and the remaining four writers favour some degree, provided it be not excessive, though when in their opinion it becomes so, they do not say. None gives a quantitative judgement, and the sum total of advice of a committee of experts and a typographical historian is neither more nor less than that given by Hansard, the printer, nearly a century before.

2. *Criterion of legibility* (36 writers in 98 years : 1827–1924).
3. *Definition of legibility* (9 writers in 44 years : 1878–1921).

These are the most important topics of all, and constitute the crux of all past and future research. They are so intimately connected that it will be wise to examine them together.

A fact eloquent of the fundamental trouble is already before the reader : *four times as many writers have measured legibility as have defined it.* Three out of every four writers have been attempting to measure something the exact nature of which they have not paused to examine. Those who are exceptions have confused the ideas of definition and criterion, and examined the nature of the latter but

[1] Except Nos. 17 and 18, which are reversed.

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inadequately, when at all. Between them, these thirty-six writers have experimented and argued with fifteen different criteria. These are: measurement by speed of reading (by the time threshold and amount read), the distance threshold (direct and peripheral), ' eye-span ', ' illumination threshold ', focus threshold, fatigue, number of eye-pauses, number of eye-refixations, regularity of eye-movements, reading rhythm, ' legibility coefficient ', ' specific legibility ', size of letters, by ' judgement of the trained human eye ', and by aesthetic merits. These criteria have been used indiscriminately under a variety of conditions, namely, in silent and in loud reading, at normal and at maximum speeds, using words (isolated and grouped) and letters (isolated and grouped), with daylight, oil, and gas-light, electric light and flash-light, with continuous reading, and brief exposures varying from one-thousandth of a second to one-tenth, and contrived with tachistoscopes of four different sorts.

All the criteria, however, have not found equal favour. The two most popular are the measurement of the distance between object and observer, direct or peripheral, these being used by eleven writers (nine and two respectively), and the speed of reading (eight writers). The number of letters or words that can be grasped at a glance is used by three, the focus threshold and illumination threshold each by two. The remaining ten criteria, mostly, though in varying degrees, of rather greater ingenuity, are each used by only one writer. In only three inquiries—and in one, on a special problem connected with railway time-tables, it was a subsidiary criterion—was measurement by the number of errors in reading. Lastly, this general lack of cohesion is intensified by writers changing their criteria as they turn from one problem to another.

Of the hundred or more authors in the Table of References, fewer than half a dozen *discuss* the selection of a criterion. Javal, for example, considers the use of the distance threshold for both normal and myopic eyes a ' quite irreproachable ' method. Cattell, in 1885, when not four or five experimental investigations into legibility had as yet been published, using an imperfect tachistoscope,[1] and both upper and lower case letters, but isolated letters in one face only, concludes with a number of suggestions for typographical reform ' now we *know* which letters are the most illegible ', assuming thereby that changes of *face* could not alter this relative legibility. (Italics mine. Apart from *prima facie* and *a priori* objections, the reader is invited to note, under the *résumé*-heading No. 8, the extent to which this study has received subsequent corroboration.) We wait until 1923 for mention (not discussion) of the fact that different writers have used different criteria, when Burtt and Basch baldly state that they know of five ways of measuring (which they name)—their own and four others. What definitions there are of course bear close relation to their authors' criteria; an author who takes ' amount read in a given time ' as criterion, gives ' ability to be read quickly ' as definition. This is the commonest definition, and ' ability to be read far off ', like its corresponding criterion, the distance threshold, is the next commonest. ' Ability to be read easily ' can hardly be paired with any particular criterion, nor is it of much value without

[1] See *Wundt, W.*

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amplification; yet it is given by three writers, but one of whom, Cohn, explains what he means by it. The one exception to such rather ineffectual efforts is A. Maire's definition, but without amplification of his physical view by one more psychological it remains incomplete.

Nobody defines legibility as ability to be read correctly, although it would have been reasonable to equate this with 'read easily'. It looks rather naïve, but is hardly more so than some, or more far-fetched than others of those offered by various writers. The merits of a definition along these lines will be discussed later, but here it may be noted that the obviousness of this definition may be one of the reasons why the corresponding criterion, errors, has been so unpopular.

Further confusion is caused by authors using a number of different terms akin to one another. Each writer might argue that the meaning of the terms he uses is obvious; yet when it has to be considered in relation to those used by others this is by no means always so. The following [1] are all in use with regard to printed letters: (1) legibility, (2) recognizability, (3) perceptibility, (4) distinguishability, (5) confusability. Visibility is also used, but its meaning is unambiguous and presents no difficulty here. In our problem, if we use (1) it is surely unnecessary to use (2), although the reverse would not be equally safe. With regard to (3), much of the work on isolated letters, especially perhaps the earlier work, really gave information about perceptibility, which was confused with, or believed to be about legibility. Both terms must be retained, but we should beware of drawing general inferences about the legibility of type-faces from the comparative perceptibility of letters; the former is our real concern. (4) and (5) are complementary; one of them might be discarded. Distinguishability, for instance, is an important element in legibility, and clearly stands in extremely close relation to, and is psychologically involved in, recognizability. A letter or word must be perceived, distinguished, and recognized before we can say that it is read. But these are fine partitions, and it is doubtful whether writers who used them in this field were deliberately, or even consciously, making the full though subtle implications which the reader is entitled to suppose they were. The trouble is, these terms have been used in discussions upon topics other than legibility, where the distinctions were important, and *in their setting* doubtless justified. But, removed from their setting, such distinctions and terms are apt to mislead, and far from simplifying the problem, introduce fresh difficulties.

4. *Faces of type* (28 writers in 101 years: 1825–1925).

This heading refers to *existing* faces (*a*) designated by their technical trade names, and (*b*) classed together here solely on account of certain common qualities.

(*a*) The quality for comparison is the relative legibility of different faces, not, for example, of the same face leaded and set solid, nor the 'atmosphere value' or affect which may accompany some faces

[1] Used by (1) most writers, (2) Cattell, (3) Hamilton, (4) Cattell, and Griffing and Franz, (5) Javal, and Sanford.

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but not others. Only two have been experimented on by more than one investigator, and each by two only. Hence no general weight of opinion exists which can be summarized. Thirty-five to forty faces (i. e. different in design, not body-size) have had judgement, experimental and *a priori*, passed upon them, twenty-six by a single experimenter. They are as follows:

| | |
|---|---|
| Norman | by Javal. |
| Garamond | |
| Jaugeon | |
| ' Block Capitals ' | by Griffing and Franz. |
| ' Roman Capitals ' | |
| ' Semi-Roman ' | |
| ' Roman Hair-Line ' | |
| ' German Gothic ' | |
| American Typewriter | by Roethlein (both in lower case and in upper case). |
| Bold Antique | |
| Bullfinch | |
| Caslon Old Style No. 540 | |
| Century Old Style | |
| „ Expanded | |
| Cheltenham Old Style | |
| „ Bold | |
| „ „ Condensed | |
| „ Italic | |
| „ Wide | |
| Clearface | |
| „ Bold | |
| „ Italic | |
| „ Bold Italic | |
| Cushing No. 2 | by Roethlein (upper and lower case). |
| „ Old Style No. 2 | |
| „ Monotone | |
| Della Robbia | |
| De Vinne No. 2 | |
| „ „ Italic | |
| Franklin Gothic | |
| Jenson Old Style No. 2 | |
| News Gothic | |
| Ronaldson Old Style No. 55 | |
| Sanserif | by Legros. |
| Blackfriars | |
| Cheltenham medium | by Burtt and Basch. |
| Baskerville Roman | |
| Bodoni | |

Roethlein's News Gothic and Legros' Sanserif are practically the same. The former's Cheltenham Old Style and Burtt and Basch's Cheltenham Medium are likewise of the same family, but not identical.

Roethlein's investigation has been quoted widely, but in my opinion her conclusions as to the relative legibility of the twenty-six faces should be accepted only with great reserve. Her technique is open to question—for example, the method of illumination, the utterance by observers of the word ' blank ', the most peculiar direction of reading, and the criterion used for isolated letters. Further tests were performed with nonsense groups, but these, being mostly unpronounceable, must have been spelt aloud, not read. She points out that the legibility of isolated letters differs from that of letters in groups or words, but fails to draw the proper conclusion. For, since letters are ordinarily printed, not singly, but in lines of adjacent groups, a valid test of the comparative legibility of faces, as distinct from letters, should involve grouped and not isolated letters. But Roethlein's tests with nonsense groups (conducted with only eight of all her types) were for corroborating the comparative legibility of the faces as tested with isolated letters. And compelling subjects to spell and not read largely deprived of its influence that grouping of the letters which normally requires ocular and psychological processes altogether different from the other arrangement. Far from corroborating by means of a more realistic control, Roethlein has only introduced a further anomalous set of conditions which themselves need a common corroboration to be of value.

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Otherwise, two general questions have been discussed: Modern versus Old Style, and Latin versus German (or 'Antiqua' versus 'Fraktur'). In the former, six out of seven judgements, some strongly, favour Old Style, the seventh (the British Association Committee's) being that there is no direct conflict, since there are good and bad faces among both, and that, provided a face is good, the style does not matter. In the latter question five out of six writers favour Latin and one is doubtful. This controversy has raged for the last thirty years, and as recently as 1921 was still continuing. A large literature devoted solely to this topic exists; but since much of it is either polemical or nationalistic, or even both, its scientific value suffers considerably, though most of the writers[1] give voluminous references. It has therefore been decided not to tabulate or discuss any opinions on the problem except those of authors who have also written and are quoted upon other questions connected with the present work. It is to these authors only that the numbers for and against, mentioned above, apply.

(*b*) Considerable agreement exists as to the superiority of fairly bold faces having open counters. But views as to condensed faces versus extended are more evenly divided. Javal, particularly, and some others stress the importance of breadth of face, broad letters being demonstrably more easily recognized. Others argue that a condensed face enables more to be read at a glance and involves fewer eye-movements, but they do not make it clear that what they desire could not be accomplished in part at least by more condensed spacing. Obviously limits, not only economic, exist to the degree to which these qualities can usefully be embodied, and no decision can be of value which ignores the psychological processes, such as the spans of distinct vision, recognition, and comprehension, involved in the act of reading. But more co-ordination of typographical with reading research is needed for a quantitative judgement.

5. *Illumination* (13 writers in 46 years: 1879–1924).

Only what is relevant to reading and the legibility of print is included here, and most of this deals with lighting in schools and the various desirable minima and conditions. Three topics are mentioned here.

(*a*) In day-lighting the optimum ratio of window- to floor-space has been subjected to some slight experimentation, but has chiefly been determined by direct observation and the tradition in hygienic practice started by Cohn. There is apparently general agreement that the best ratio is between 1 to 5 and 1 to 4.

(*b*) There is less agreement as to the position of the light source in relation to the reader. Five writers prefer it on the reader's left and one to his front, while two favour vertical day-lighting and five oblique.

(*c*) The influence of artificial illumination has received rather wider scientific treatment and more experimentation. The earlier work is now largely obsolete, since it dealt with oil and gas illuminants. But two writers recommend a minimum of 5 foot-candles and an optimum of 10, and another a minimum of 100 metre-candles. It would seem

[1] e.g. Burgerstein, L. and Netolitzky, A. (1902); Kirsch, R. (1920); Radojevic, S. (1921); Wick, W. (1921 and 1922).

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that the most important problem is to find with certainty (for there is still controversy on this point), not an optimum illumination value, but the limits inside which a given change produces a large effect on the reading performance, whether in speed or accuracy, or through fatigue or risk of injury, and outside which only a slight proportional effect is produced ; in a word, the safe region of illumination. This, and the colour and spectral composition of light are technical problems which need further investigation before they can be linked to the present work.

6. *Indentation* (4 writers in 13 years : 1905–17).

In 1905 indentation (at the right ends of lines) is desirable because it prevents any impression of monotony. In 1906 it is undesirable (at either end) because it upsets the reading rhythm, which in 1912 it assists, and is therefore again desirable. No evidence is offered for the last view, whereas that in favour of the preceding one, obtained from photographs of eye-movements, if not conclusive, is detailed, technically weighty, and experimental. The fourth inquiry, in 1917, showed that indentation (at left end) was of very slight assistance for a special purpose, but no inference as to general application can be drawn from this instance.

7. *Leading* (20 writers in 46 years : 1880–1925).

Confusion has been apt to arise owing to the misuse by laymen of a technical printing term. On the printed page *some* space between the lines is always visible, but ' leading ' properly refers to strips of lead inserted between the rows of metal shanks bearing on their ends the reverse letter-shapes, in order specially to alter the ratio of height of letter to interlinear space which is customary for a given face, and is produced by determining in the first place in the design how tall or short a letter shall be cut upon the given cross-section of the shank. One finds the term frequently used, however, to denote the total width of interlinear space. A satisfactory term for this is ' interlineage '.

Forty per cent. of the writers included here are concerned only with interlineage. Some recommend certain figures for the absolute width—2·5 mm. is mostly favoured as a minimum—others think that more important is the ratio of interlineage to gauge of letter or (one early writer) to length of line. The question of which is more important—dimension or ratio—applies equally to leading and to interlineage, but the actual numerical answers must differ.

Another influence, language, makes it certain that the same dimensions will not be the best in all cases, for in French the frequent occurrence, and in English the absence of, accents alter the effective ratio of the gauge of a face to its interlineage.

Of those who deal with leading proper, nine favour it and three are opposed. Of its nine supporters five base their decisions on experiments, of its three opponents none. Another writer is doubtful, opining that there may be utility in leading, but only after certain other minimum requirements have been fulfilled. Of the five experimental inquiries one was concerned with the special problem mentioned under *Résumé* No. 6, and in another it was not the

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author's principal concern, but his method, eye-photography, was sound, and, in the light of subsequent work on this technique, must carry considerable weight. In a third inquiry two writers find that a proportionally slight increase in the amount read was obtained by what amounted to a little over 1-point of leading. In the most recent inquiry a maximum average gain of 6 per cent. in speed was obtained with striking absence of exceptions. The same objections must be made to the illumination and to subjects' exclaiming 'blank' for words they could not read without slackening speed, as in Roethlein's case, but here a valid control was exercised by a more realistic day-light series. But I am not concerned, any more than its author, to claim finality for this inquiry; on the contrary, I wish to emphasize that any view is disputable and to indicate in what direction the *weight* of serious evidence appears to point.

Of the three opponents of leading, the earliest measured by the distance threshold, and in only the most rough-and-ready tests, for which he gives no figures. The second was thinking purely in terms of the fifteenth-century Venetian tradition; while the third, whose opinion is *a priori*, may have been influenced by the vigorous views of Javal himself.

Leading has been disputed almost as hotly as any other typographical question. Half, or more, of the views published are really *a priori*, and it would still appear to be, and prior to 1921 indubitably was, an open question. Yet many of the opinions expressed, and *all* of those antagonistic to leading, have been pronounced as though the matter were definitely solved, and its solution well known. Yet nine writers support leading, one is uncertain, and three object to it. This cannot be called unanimity.

8. '*Legibility*' *of letters* (12 writers in 41 years: 1885–1925).

The relative legibility of the letters of the alphabet has been calculated and published in full in ten instances, the criteria being the time taken (2), the distance threshold (5), and errors (3). Seven tests were with upper case, only three with lower case, and in many other experiments on legibility upper case is chosen. Yet, except for experiments on visual acuity, it is difficult to understand why. Since roughly 99 per cent. of all reading must be with lower case letters, to obtain knowledge upon the latter is presumably the more important. Perhaps, too, the use of upper case letters, and their association in experimenters' minds with visual acuity test-cards, may partly explain the general predilection for isolated letters.

Only three authors appear to realize that the relative legibility of letters may be influenced by the design of the face and vary with it, although another considers this improbable, or at any rate outweighed by other factors.

Tables 1 and 2 show the correlation coefficients[1] between all the 'legibility orders' referred to, for upper and lower case.

[1] The formula $R = 1 - \frac{6 \Sigma \delta^2}{n(n^2 - 1)}$, where $R$ = the rank correlation coefficient, $\delta$ = the difference between ranks of paired measurements, $n$ = the number of cases, was used throughout this work for the calculation of correlation coefficients. Those which are not less than three times greater than their probable error are taken as significant, and are printed in heavy type.

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TABLE 1

UPPER CASE.

| *Correlation coefficient of* | *Cattell.* | *Finzi.* | *Kirschmann.* | *Roethlein.* | *Hartridge and Owen.* | *Banister, Hartridge, and Lythgoe. 'Method I'.* | *Banister, Hartridge, and Lythgoe. 'Method II'.* |
|---|---|---|---|---|---|---|---|
| with Cattell | — | −0·05 | −0·19 | +0·12 | +0·08 | −0·15 | −0·26 |
| „ Finzi | −0·05 | — | +0·10 | +0·19 | **+0·46** | +0·14 | +0·10 |
| „ Kirschmann | −0·19 | +0·10 | — | +0·32 | **+0·53** | **+0·52** | +0·31 |
| „ Roethlein | +0·12 | +0·19 | +0·32 | — | **+0·43** | +0·24 | +0·08 |
| „ Hartridge and Owen | +0·08 | **+0·46** | **+0·53** | **+0·43** | — | **+0·71** | **+0·66** |
| „ Banister, Hartridge, and Lythgoe 'I' | −0·15 | +0·14 | **+0·52** | +0·24 | +0·71 | — | **+0·81** |
| „ Banister, Hartridge, and Lythgoe 'II' | −0·26 | +0·10 | +0·31 | +0·08 | +0·66 | **+0·81** | — |

TABLE 2

LOWER CASE.

| *Correlation coefficient of* | *Cattell.* | *Sanford.* | *Roethlein.* |
|---|---|---|---|
| with Cattell | — | **+0·52** | **+0·56** |
| „ Sanford | **+0·52** | — | **+0·67** |
| „ Roethlein | **+0·56** | **+0·67** | — |

In Table 1 only 33⅓ per cent. have significance, and these predominantly among the later experiments. It is surprising that the coefficient between Kirschmann and Hartridge & Owen should be so high in view of the diversity of conditions, not the least important being that Kirschmann used peripheral, Hartridge and Owen direct vision.

In Table 2 all three coefficients are significant, though not, except when compared with those in Table 1, remarkably so. It is difficult to explain why these figures are higher, since about as great variety of conditions obtained as in the upper case experiments.

Besides the figures in these tables, however, writers have drawn various conclusions ; for example, that broad letters are more legible than narrow or tall ; that, on the contrary, ascenders are more legible than descenders or any others ; that simple shapes are better than complicated, and angular than curved. Javal asserts that a, c, and s are the worst letters of the alphabet, and certainly they are among the worst eight in all the above lower-case investigations. But his other opinions on the relative merits of existing letter shapes find no striking confirmation from the experiments quoted under the present heading. Nor need this altogether cause surprise when the influence of language is remembered. Men of three nationalities have worked in this field, Germans, French, and English and Americans (the last two are the same for this purpose), and the commonest letter-combinations are different in each language. But a given letter is more illegible when near some than others. In one language, therefore, it may habitually be accompanied by those of evil influence, in another not. In other words, its readers will have become predominantly familiarized with it in what is either an unfavourable or a favourable setting for it : according as this is so a letter will be called illegible in one language, legible in another.[1] Possibly some of Javal's, and other of the above generalizations are true, but it would seem, on consideration of the discrepancies both in these numerical results and in the experimental conditions from which they were engendered, that no single objective set of relations between the legibility of the letters can yet be said to have been established.

9. *Length of line* (13 writers in 43 years : 1881–1923).

This is one of the few fields in which research begins to show a steady trend. All but one early writer make definite numerical recommendations. Of these twelve, only half present proposals enabling general comparison. Of the remainder, two recommend lines of given lengths in terms of the number of words, two of the number of ems, and one in no linear unit, but as a ratio of line-length to interlineage. The other six propose figures of minimum, maximum, and/or optimum lengths, which are summarized, with certain other details, in Table 3.

[1] For other remarks upon the influence of language see under Heading No. 17.

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TABLE 3

| *Author.* | *Date.* | *Criterion.* | *Minimum.* | *Maximum.* | *Optimum.* |
|---|---|---|---|---|---|
| Weber | 1881 | Speed | 100 mm. | 150 mm. | 125 mm. |
| Cohn | 1883 | Fatigue on eye | 90 mm.[1] | {110 mm.[2] / 100 mm.[1]} | 95 mm.[1] |
| Dearborn | 1906 | Speed | — | — | 80 mm.[1] |
| Ruediger | 1907 | Speed | — | — | 80 mm. |
| Maire | 1908 | — | — | 100 mm. | — |
| Huey | 1910 | Speed and Fatigue | — | — | 60 mm. |
| Brit. Assoc. | 1912 | Fatigue on eye | — | 93 mm. | — |

[1] For letters of lower case with gauge of 1·5 mm.
[2] For letters of lower case with gauge greater than 1·5 mm.
The other figures are applied by their authors to letters of any gauge.

There is an obvious tendency to recommend shorter lines as time goes on, whether in terms of minimum, maximum, or optimum; and no recommendation in the contrary sense is known of. Whether length of line should be fixed irrespective of other typographical conditions, or in part depend on gauge, interlineage, face, or subject-matter, has not yet been properly investigated; till then the above figures may be of little practical value. In any case they provide some sort of scale with which to relate further experiments.

10. *Margin* (9 writers in 42 years: 1881–1922).

One writer only, the earliest, considers margins 'superfluous'. Three alone suggest relative widths for the margins of a page; the remainder scarcely do more than assert that margins are desirable. There are the usual variety of criteria and absence of experiments. However, the *a priori* findings are fairly tentative.

But the real cleavage is with the printers. Their tradition lays it down that the inner margin should be narrowest, the top next, the outer next, and the bottom widest, and some printers even demand rigid proportions between these. Their reason is aesthetic—that the double page is the proper unit, and that this arrangement 'looks best'. But this is a convention unrelated to practical needs. The opposite arrangement of side margins is entitled to at least equal consideration, but it has been left for those concerned with reading-hygiene to point this out. An increase in the inner margins according to the thickness of the book would also be a more rational principle.

Whether this matter is important or not is immaterial here. The disagreement emphasizes again how inadequately the most important quality of printed matter—its legibility—has been fostered, where it might most have expected support, and how ineffectually the problem has often been attacked.

11. *Paper and ink* (20 writers in 99 years: 1827–1925).

(*a*) *Paper*. There are two principal questions—colour and other qualities. The former becomes a choice between white, and yellow to cream. Six writers favour white, and five yellow or cream; the only other colour recommended is pale grey, which was preferred to white or yellow by one writer in 1881, and to yellow, but not white, by two in 1896. Except for the latter, no account of any thorough experimental research appears to have been published, though one



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can have nothing but admiration for the attempt made by Babbage a century ago, and especially for the exemplary chapter in which he discusses the matter. In any case, the question is undoubtedly not yet a closed one.

On the other qualities there is general agreement: paper should be hard, smooth, of a minimum thickness, and unglazed. It should be hard and smooth to ensure to the impression a sharp outline, and the same dimensions as the metal letter which marks it; unribbed to prevent distortion of the letters; and thick enough to prevent the print on the reverse side showing through. It should be unglazed to prevent glare, and because, when the paper is glossy, the print is easily apt to become invisible at certain points. Further, if the paper acts like a mirror, the eye's accommodation is disturbed. Most of the judgements are qualitative, but a very detailed paper was published in 1915, which gives much useful quantitative advice. One writer believes that paper-quality and texture are 'a much less significant factor than has been supposed', but this view is apparently founded on her own experiments, which would not be difficult to criticize as a basis for such a generalization.

(*b*) *Ink.* This, it is generally agreed, should be dead black, but the question has not yet received very wide attention from writers such as are being considered in this survey.

12. '*Projectors*', *or long sorts* (i. e. characters which project above or below the line or do both) (4 writers in 98 years: 1827–1924).

These refer to letters and figures. In neither have proper experiments been carried out, while the reasons for writers' preferences are as various as usual.

For letters one writer favours ascenders, and long ones, because their 'breaking the monotony . . . prevents fatigue'; the other, although he puts ascenders among the most legible of existing letters, would nevertheless do away with them, and shorten the tails of descenders. His reasons are obscure; he appears to have conducted rough tests (but gives no figures), using the distance threshold, but, since he agrees by implication that the field of distinct vision covers roughly the upper half of a letter, it seems strange that he should recommend abolishing ascenders while merely curtailing descenders, rather than vice-versa.

For figures the earliest writer, having in mind principally tables, objects to projectors as interfering with interlineage; the next favours them because they make the figures less 'confusable'; while the latest, also chiefly considering figure-texts, favours them because they help one to keep the place, and objects to them because they are distracting, and, in the metal, fragile.

These views may go as far in *a priori* argument as is possible, but it is not far enough. Reasoning which leads the same writer to recommend projectors because they facilitate keeping the place, and to reject them because they distract, is unlikely, it must be evident, ever to indicate any very productive line of research, and had much better be abandoned forthwith. There is some justification for introducing practical arguments about fragility. Unlike letters, figures must be read singly, not in groups, and they have generally

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no context by which, if one is passed over, it may be inferred. Hence it is particularly important that each figure should be legible, and its shape, therefore, preserved.

13. *Punctuation* (3 writers in 32 years : 1885–1916).

This has received less attention than other typographical questions. Nevertheless, it was summarily denounced forty years ago, though with little reasoned argument and no experimentation, an alternative being suggested by the same author as an improvement. This alleged improvement, however, as was pointed out only thirty-two years later, even if desirable, is not practicable.

14. *Serifs* (12 writers in 98 years : 1825–1922).

There are two questions : are serifs desirable ? If so, of what shape ? Explicitly or implicitly, nine writers approve of serifs, the reason, where stated, being generally that they overcome the harmful effects of irradiation. Four writers experimented, the rest rely entirely on the demonstrable optical effects mentioned. Of the four the most cogent argument of any length is Legros' and Grant's, in favour, based on certain calculations of the face-dimensions. In so far as their method compasses the problem (it ignores the psychological aspect), it seems *a priori* unanswerable. Nevertheless, Roethlein's experiments, though not to be implicitly relied upon, do not altogether support their view. Roethlein's work is mentioned again here only to reinforce the fact that what experimental evidence exists is not unanimous.

Of the two other experimenters, one, arguing from his own tests, doubts the utility ' of all ornaments ' ; the other gives a qualified approval, based on rather questionable experiments with upper case only.

As to general shape, there is complete agreement : serifs should be triangular, fairly thick, and short, rather than rectangular, thin, and long. Theoretically, this view would seem to be correct—there are a number of good reasons against the latter variety. Yet it is extensively used by printers, who may be unacquainted with the weight of opinion, but have not, to my knowledge, explained their own preference. Wider and, if possible, more conclusive experimentation would not be superfluous.

15. *Size of type* (18 writers in 98 years : 1827–1924).

Here, likewise, are two principal questions : (*a*) how important an influence is the size of type (i.e. the gauge) on legibility ? (*b*) Of what dimensions should types be ?

(*a*) Two answers have been given : that absolute size is much the most important influence ; and that it is not. The former implies that legibility varies in something like direct proportion to size ; the latter includes two views. One is that the largest influence on legibility is exerted by a combination of factors, of which size is but one ; the other is that, if there is any relation between legibility and size of type, it is inverse. Six writers declare size the most important factor in legibility ; five think otherwise. Of the six, five argue from experiments and one apparently is influenced by the writers

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before him. Of the other five, three experimented, and two argue deductively. Of these three, one found that only a very slight change was effected by doubling or halving the gauge; another found a slight inverse relation; and the third, like the two who made no experiments, thinks that the ratio of gauge to interlineage should be stressed rather than the absolute gauge. (Two others think that the gauge should be determined partly in relation to width of mainstroke, though they do not stress it.)

It is interesting to compare the criteria by which these seven experimental judgements (for this is a problem to be settled *par excellence* by experiment) are made. Of the writers who believe in the efficacy of size, two judged by speed (amount read in brief exposures, and time taken in continuous reading), one by the illumination, and three by the distance threshold. From the other camp two experimenters (the third is irrelevant here) judged by the speed of reading as measured by the number (one by the duration also) of the eye's reading pauses. This, in my opinion, is a reasonable method of judgement, the distance and illumination thresholds not. Experiments hardly seem necessary to demonstrate that in failing light big type remains readable longer than small, or that large letters can be read farther off than little ones. Such ways of measuring are bound to make pure size seem the governing influence on legibility, for they are employed in settings which engender the result. But these settings are artificial; they can never possess any true connexion with the realistic conditions of legibility proper. We are virtually left, then, with a conflict between four writers measuring by speed: two according to amount read and time taken, who stress size, and two according to eye-pauses, who make little of it. *Ceteris paribus*, I favour the latter method, as more refined and certain. In any case, the conflict may well be more apparent than real. Size may prove the governing influence both below and above certain limits, but not between; varying directly with the legibility of *very* small faces, and inversely with that of *very* large. This would explain why one experimenter, contrasting types of the former class, found a direct relation, while another, contrasting some which were intermediate, found none.

(*b*) It remains to tabulate the numerical recommendations. These are hardly numerous enough for comment, except that only about half are based on experiments, and the criteria are as mixed as ever. The details are presented in Table 4:

16. *Spacing* (18 writers in 44 years: 1881–1924).

'Spacing' technically refers to horizontal space, never to leading or interlineage; it is employed only in its technical sense in these pages. Little general discussion is possible, for most of what has been written consists of specific recommendations for the various space-widths. Criteria (as heterogeneous as ever) are given by 55 per cent. of the writers only. There are six among ten writers, fatigue and speed being the favourites. Only two inquiries are based on experiments, although some of the remainder are clinical or statistical inquiries in schools. There is a tendency, not confined to the present topic, for successive writers to be content uncritically to

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## Table 4

| Date. | Basis. | Criterion. | Gauge (lower case small sorts). Minimum. | Maximum. | Optimum. | Ratio of gauge to width of mainstroke. | Ratio of gauge to interlineage. Antiqua. | Fraktur. |
|---|---|---|---|---|---|---|---|---|
| 1881 | Experimental | Speed | 1·5 mm. | 2 mm. | — | — | 1·50 : 1·75 | 1·5 : 2 |
| 1886 (?) | ? | ? | — | — | — | 5 : 1 | — | — |
| 1886 (?) | ? | ? | — | — | — | 5 : 1 | — | — |
| 1896 | Experimental | Illumination | 1·5 mm. | — | — | — | — | — |
| 1905 | ,, | Distance | — | — | 9-point | — | — | — |
| 1910 | *A priori* | Speed and fatigue | — | 2 mm. | — | — | — | — |
| 1911 | ,, | ? | 1·5 mm. | — | — | — | — | — |

## Table 5

| Date. | Basis. | Criterion. | Minimum space (in mm.) 1 between main-strokes of letters. | 2 between letters. | 3 between words. | No. of letters per 100 mm. Maximum. | Minimum. | Optimum. |
|---|---|---|---|---|---|---|---|---|
| 1881 | Experimental | Speed | — | — | — | 60 | 50 | 60 |
| 1883 | School inspections | — | 1 (when gauge is 1·5) | Wider than in 1 | 3 (when gauge is 1·5) | 48 | — | — |
| 1884 | ? | ? | 0·3 | — | — | — | — | — |
| 1896 | School inspections | ? | 0·5 | 0·5—0·75 | 2 | 65 | — | — |
| 1902 | School inspections | — | — | Wider than in 1 | 2 | 65 | — | — |
| 1911 | *A priori* | — | 0·5 | 0·5—0·75 | 2 | — | — | — |
| 1912 | Statistical | Strain on child's eye | — | — | — | 54 (in school-books) | — | — |
| 1914 | *A priori* | Irradiation | — | Wider than in 1 | — | — | — | — |
| 1916 | — | — | — | — | The en-quad | — | — | — |

adopt the opinions of some early writer like Cohn, and to make no further attempt to subject the matter to fresh and more complete experimental treatment.

Recommendations are summarized in Table 5. As with size of type, there are two kinds, absolute and relative minima, maxima, &c.

There has apparently been no tendency in any particular direction during the period reviewed.

18. *Thickness of limbs* (12 writers in 33 years : 1878–1912).

The weight of general opinion is that limbs should be ' rather thick ' (needless to say, for various reasons), in that most writers think either that thickness does not matter, or that it is positively advisable. Numerical recommendations are summarized in :

TABLE 6

| *Date.* | *Basis.* | *Criterion.* | *Minimum width of main stroke in mm.* | *Ratio of main-stroke to gauge.* |
|---|---|---|---|---|
| 1883 | School inspections | Strain on child's eye | 0·25 | — |
| | | | (Schoolbooks) | — |
| 1884 | ? | ? | 0·30 | — |
| 188(5 ?) | ? | ? | — | 1 : 5 |
| 188(5 ?) | ? | ? | — | 1 : 5 |
| 1896 | School inspections | ? | 0·30 | — |
| 1911 | *A priori* | ? | 0·25 | — |
| 1912 | Experimental | Distance from eye | 0·30 | — |

No general trend of judgements is discernible, nor are the results very impressive. Nevertheless, they represent the sum total of advice, which, in accordance with custom, becomes more authoritative, the fewer the experiments.

17. ' *The Ideal Type* ' (13 writers in 47 years : 1788–1924).

Some of these judgements are general, some specific ; some are negative—chiefly those which are general—others positive. The general are not much more than summaries of each writer's miscellaneous recommendations for typographical reform, and cover a wide range. Roughly, they amount to this : A type-face should be simple, fairly broad, with fairly thick limbs, but not too much contrast of thickness and thinness, and with fairly wide spacing. These are pretty generally agreed upon. *A priori* they seem impeccable, and though their value must be restricted until actual figures for the various dimensions can be confidently and definitively prescribed, it would be of use to be certain of this much.

There remain three sets of specific and detailed recommendations for the design of most or all of the letters separately. It is hardly possible to summarize these ; they need individual examination. They contain points of agreement, also contradictions. One writer thinks there are too many letters, naming those he would abolish ; two others would make additions. Many of the suggestions are extremely interesting, especially Javal's, who was in this respect a pioneer. But it would be difficult to make any progress in estimating their utility, unless these types were cut and made available for experimentation. It is certain, I think, that every printer would

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scoff at them, or anyway feel averse from the designs: they are totally opposed to the conventions and aesthetics of typography. But a study of the history of printing should prepare one to expect that any purely utilitarian or scientific recommendations are bound to conflict to some extent with these traditions, and the battle might be worth joining.

Finally, some reference should be made to the influence of language. The commonest letter combinations and the associations most likely to be aroused by a given letter, say, b, are different in different languages. Now, since the letters to which b finds itself in most frequent proximity must take a large share in determining the confusions made in respect of it, the errors, if any, which are committed when b is read by a Frenchman, will be likely to differ from those committed by an Englishman or a German. Hence language may influence the ideal shape recommended for each letter.

In conclusion of this general survey, it is worth reiterating how extraordinarily little solid agreement is to be found over the whole field of typographical investigation. In only three branches, viz. length of line, quality of paper (not colour), and serifs, is there any worth mentioning. It is also evident that for any progress to be made in future less attention must be paid to theorizing, and much more to careful experimentation.

## III. THE PROBLEM

### 1. Theoretical

#### (a) *Definition*

The definition of legibility is of the utmost importance, for on it will depend to a large extent the criterion, and on the criterion the nature of any experiments that are made. The definition must also influence our estimate of past research.

Legibility must be distinguished from terms like recognizability, perceptibility, &c. With these we are not concerned. Legibility has to do with reading. Normal reading refers to an act performed most commonly by an individual in an ordinary sitting position in a full light, with words set in horizontal lines one below the other, printed, as to about 90 per cent. in lower case, as to about 10 per cent. in upper case, in black ink on white or cream paper. The letters, spaces, and lines are of sizes and proportions which vary within certain limits. The matter is held at distances from the eye varying generally between about six and sixteen inches.

A legible type means one which can be easily read *under these conditions*. To read means to obtain meaning from written or printed symbols. But does 'easily' mean accurately, or rapidly, or both? Or does it mean with little effort, and if so, does that mean without eye-strain or without fatigue (both the latter involve some reference to an extended duration in time; accuracy and rapidity do not)? It does not follow, because you read accurately, or rapidly, or both, that you do so without effort (it may be only by an effort that you do either); nor that you read accurately or fast because over a long

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period you read without eye-strain or fatigue. To decide which of these terms to retain as elements of our definition apply the test of *reductio ad absurdum*.

Imagine inaccuracy in reading indefinitely increased. A point comes at which the reader is obtaining meanings practically none of which are those symbolized by the print. The operation has ceased to be reading, and a type which produced this result might therefore be called illegible.

Next, imagine the rate of reading indefinitely diminished. The operation after this change, it would still, but only just, be possible to call reading, though it would have become very like spelling. Ability to be read rapidly, therefore, can for practical purposes just be used as a definition, although theoretically it is on the border line of failure. This definition is complementary to our first. For of two types read with equal accuracy, that which was read faster might claim to be the more legible, and of two read equally fast the one read more accurately likewise. Neither accuracy nor rapidity then is a complete definition in itself, but both are essential ingredients, and define legibility in terms of reading, but the two other proposed definitions are bound to be in terms of ideas extraneous to the reading process itself, and referring to some physical state produced in the reader. But such states (e. g. fatigue, eye-strain) can also be produced by very many other causes, and consequently are most unsuitable for a definition of legibility, which should be in terms of the reading process itself, and one which logically permits the choice as criterion of some standard of performance which *can* be measured.

We have examined the mental aspect of legibility, and the legibility of a continuous text, because this is the most important practical problem, although it is preceded logically (but not, necessarily, psychologically) by the legibility of letters and words. But the optical element cannot be omitted. In this sense, to quote Maire, the legibility of a letter consists ' in it being possible to define clearly with the eye the design of a letter, that is, its contours, and therefore the *ensemble* of the letters in a single word '. The eye must be able to pick out the shape of a letter; to be able merely to distinguish a letter as a mark from either its background or other marks, comprises not legibility, but visibility. We arrive then at the following. Legibility refers to (1) letters, (2) words, and (3) continuous texts. Its essential and sufficient conditions are that it should be possible: (1) with letters, for the eye to define clearly the shape of a letter; (2) with words, the collective shape of a word; and (3) with continuous texts, to read a type both accurately and fast.

### (b) *Material*

In introducing in the last section the question of letters, *individual* letters were not equated with *isolated* letters, for to do so would be a serious step away from realistic conditions of reading. Nevertheless, it has been a frequent mistake. Still, it will not be necessary to experiment only with ordinary English prose. To keep close to normal conditions is not to reproduce them, nor is the latter feasible if they are to be controlled as we require.

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Obvious disadvantages would attend the use of passages already familiar to readers. But it might also be difficult to exclude completely the factors of association and fragmentary memory (which would probably influence speed and accuracy) in matter which was unknown, but in the readers' language. An alternative might have been to use a foreign language. But even this procedure has disadvantages, apart from the practical difficulty of finding a suitable language previously unknown to all the subjects, since in this case a little knowledge would be a very dangerous thing. Even in an unknown (European) tongue, it is extremely probable that some words or terminations with a perceptible resemblance to others in the readers' language (henceforward presumed to be English) would sooner or later occur, and these words would probably be different for different readers. Further, if a foreign word, which seems like an English one, recurs frequently enough in its own setting, it is almost inevitable that readers will gradually try to infer its meaning. But influences such as these are bound to make less comparable the results of each of the subjects. And we shall in any case be handicapped by considerable difficulties due to numerous individual differences.

Now, one could obtain all the advantages of an unknown foreign tongue, and avoid its disadvantages with a nonsense language. Of course, even this will arouse some associations, and it may also be unconsciously flavoured by the person who concocts it in ways which will taint the experiments, whether according to his moods, his susceptibility to verbal affects, or the languages which he himself understands, and the reader also will be influenced in these ways. Finally, the normal relative frequency of the letters of the alphabet should not be seriously altered in the nonsense.

The fact that one stimulus arouses different associations in different people is a fundamental human condition which can never be wholly eliminated. It could, however, be rendered in the present case appreciably less harmful, first, by choosing subjects unfamiliar with any tongue but their own, or, failing that, knowing only the same languages as one another, and secondly, by the use of a nonsense language from which all the vowels had been extracted. The ' words ' would then be unpronounceable, and therefore less capable in themselves of evoking sound associations ; and, since the subject could never have encountered in English vowelless words, these would be less likely to evoke visual memories. But, first, information would always be missing upon six letters, which, if we remember that some letters are commoner than others, together make up about 35 per cent. of an average page of print. Secondly, subjects would have to spell, instead of reading. Thirdly, groups of consonants could not be apperceived in the units employed by the eye and mind in normal reading. On the one hand, these differences would compel closer study of the print and prevent guessing, but on the other they would substitute psychological processes not involved in reading proper. This has not always been considered a drawback. Some experimenters, for instance, have drawn for analogies, and even constructed test material upon the principles underlying the special process of proof-reading. However, the use of vowelless nonsense

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approaches, if it does not comprise, the limiting case to realistic conditions. Still, this danger of artificiality is believed to come about rather more subtly than what has been written here about realism might lead one to suppose.

A critic might object that it is as unrealistic to spell out groups of consonants as to name isolated letters. In both cases, it is true, each letter is named singly, but the *setting* in the second case is artificial, and in the first almost normal. And it is to some extent to the ordinary setting of the whole performance of reading, to the familiar complex itself, as such, that a reader reacts, as well as to changes in the typographical stimulus. Judd,[1] arguing from experiments, says : ' The sensory conditions of reading are of less importance than the established habits of recognition. . . . That which a reader recognizes at each fixation is largely a product of training. Equipped with mature powers of recognition an individual will behave in the same way even where there is a difference in sensory material.' Again, O'Brien asserts that ' the unit of recognition . . . [and] consequently the rate of reading . . . are but very slightly affected by changes in the sensory content—for example, by changes in the size of type.' Of the artificialities, therefore, which must be introduced into the experiments, those are to be preferred which do least violence to the familiar complex and to the normal reading behaviour of the subjects.

To return to the drawbacks to a nonsense language. The normal relative frequency of the letters of the alphabet could be best preserved by selecting a piece of prose of which the vocabulary is not specialized, and rearranging the letters so as to produce nonsense.

In the prose in natural form (to be called ' sense ' or ' sense-material '), various restrictions would be desirable. First, diversity of content is to be avoided. It seems probable that the nature of the subject-matter has some influence upon the reading performance, at any rate on speed. Secondly (this may or may not apply to nonsense—see Beer, M.), since the length of words also may apparently influence speed, though it is not certain precisely in what way or how far, wide differences in the average word-length should be avoided. Lastly, it is well to print no figures, italics, or abbreviations.

To sum up : in order to retain in the laboratory a maximum of the reading conditions of real life, a threefold treatment of the test-material, at any rate in preliminary experiments, is advisable ; first in the shape of vowelless nonsense groups, next of nonsense with vowels, and last, of ordinary prose. Certain disadvantages in each form this triplication cannot abolish, but it offers advantages unobtainable through any of them singly, and to some extent provides mutual checks.

Subsequently, totally different experiments might be devised for corroboration. But this question is postponed to § IV.

### (c) *Criterion*

Most writers have either confused the criterion of legibility with the definition or neglected one of them. The problem is not merely

[1] See Judd, C. H. (1918).

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how to choose a criterion, but to distinguish between what legibility means, how to measure it, and on what it depends. One must guard, for instance, against declaring or implying alternately something to be criterion and cause, such as size of letters, merely because it might logically be either.

The criteria hitherto used divide themselves into three categories, which may be termed (1) objective, (2) subjective, (3) functional.

(1) An objective criterion of legibility is one which measures certain dimensions, and/or ratios of dimensions of the printed symbols.

(2) A subjective criterion measures certain passive states within the person of the reader, which are produced by the reading performance.

(3) A functional criterion measures the results of certain active performances carried out either consciously or unconsciously by the reader in the process of reading.

The criteria used by previous writers may now be classified thus :

| 1. *Objective.* | 2. *Subjective.* | 3. *Functional.* |
|---|---|---|
| Size of letters. | Fatigue. | Distance threshold. |
| ' Legibility coefficient.' | Eye-strain. | Illumination threshold. |
| ' Specific legibility.' | Aesthetic satisfaction. | Focus threshold. |
| | ' Judgement of the trained human eye.' | Speed of reading. |
| | | Errors. |
| | | Width of eye-span (i. e. the visual angle subtended by the group of letters which can be appreciated in one eye-pause) or duration of eye-pause. |
| | | No. of eye-pauses per line. |
| | | No. of eye-refixations (i. e. the fixation by the eye of a point a second time to correct an error in the first fixation. A return movement is involved). |
| | | Regularity of eye-movements. |
| | | Reading rhythm. |

(1) An objective criterion implies a conception of legibility which is restricted to the essentially physical aspect, and to that extent burkes the question, seeing that the ultimate and most crucial problem is psychological, namely whether such a thing as objective legibility exists at all. Further, though not incompatible, this class bears no direct relation to our definition.

The finest and most reliable of the objective criteria would seem to be ' specific legibility '. But its explanation is elaborate, and the reader is referred to Historical Subject-*Résumé* No. 2 (Legros and Grant, 1916).

(2) The subjective class measures not by any typographical unit, but by some mental or physical state which can also normally be produced by other than typographical stimuli. Moreover, all mental and physical states themselves need to be measured in terms of something else. This class of criterion therefore achieves but indirect contact with its material. There is further the risk of measuring the mental or physical state—fatigue, for instance—in terms of the reading performance, and the reading performance, *qua* index of legibility, in terms of the mental or physical state, i. e. fatigue. It is logically essential that those states be measured by altogether different tests.

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But in the present condition of knowledge about the nature of states such as fatigue, &c., this is not possible.

As to the 'judgement of the trained human eye', this criterion is too vague to serve our present purpose.

Lastly, all the criteria of this class fail to measure legibility as we have defined it.

(3) In my opinion a type can most properly be tested for legibility by actually being read. A criterion of class (3) is capable of measuring in experiments something which also occurs in ordinary life, and though it measures less finely than 'specific legibility', it springs from a more comprehensive aspect of the process of reading. Furthermore, most of the criteria of this class fit our definition, and measure what we intend to measure.

In the criteria of the functional class the first five are different from the last five. The former measure the results of conscious, the latter of unconscious processes. The former relate to the complete, final process which is compound; in so far they are both physiological and psychological. The latter relate only to component processes, which are principally physiological. To some extent it is an advantage that the second five measure unconscious processes: one can be more sure that subjects are doing exactly what is wanted, and that the factor to be measured is not being influenced by irrelevant motives in the subject. On the other hand, it seems doubtful if sufficient is really known about eye-movements in reading—especially their causal connexions.

Besides, a word or letter can be misread without the error being revealed by the behaviour of the eye. In other words, reading accuracy would never obtain adequate measurement by optical methods. Again, we have as yet no good reason to suppose that an unbroken direct relation subsists between legibility and these physiological processes. Experimental evidence [1] goes to show that the number of eye-movements and pauses are never 'merely adjustments of the eyes to the sensory material' [2]; that they scarcely alter in response to a 50 per cent. decrease or 100 per cent. increase in the size of type; but that they may fluctuate widely in any individual. (In any case, to measure the number of pauses alone would be inadequate, since a smaller number of pauses may be counteracted by a longer average duration, and a shorter duration by a larger number.) It is only to the use of eye-movement factors as a sole, final criterion of legibility that objection is taken. There are doubtless other problems of legibility and reading to which they are well suited. The best course might be to use an eye-movement factor in conjunction with one of the first five criteria.

Of these the distance and the illumination thresholds fail on the score of realism. To hold the print at or beyond the threshold, whereas in ordinary life it is invariably held well within, and to measure legibility by the absolute maximum distance or minimum illumination required for some sort of reading performance, irrespective of the range of distances or illuminations which constitutes the normal, is a travesty. Moreover, the distance method involves a special assumption. By increasing the distance of a type from the

[1] See Dearborn, Schmidt. [2] Judd.

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reader, you decrease its size. And the introduction of this variable assumes that a comparison of the legibility of different faces is not affected by a disparate alteration of their sizes. But it is psychologically unwarrantable to assume that to reduce thus *in effect* the size of a face is the equivalent of actually printing it smaller, while keeping the distance constant.

The focus threshold involves both unrealistic conditions and *in effect* (partly owing to practical difficulties) variations in size of face (though these would probably be smaller than by the distance method). This criterion does not run counter to the sense of our definition, but it would compel most attention to accuracy and least to rapidity.

There remain speed and errors. Although incomplete separately, together they are complementary, and logically they fit our definition better, and involve fewer modifications to the normal reading performance and its setting than the other criteria. Even so there are difficulties.

In reading 'sense' (but not nonsense) mistakes are likely to be determined predominantly by associations, and only to a lesser degree by typographical factors. Further, since a reader can often infer, without looking, the last part of a word, or even sentence, from the first, an error in the first part may *cause* others in the second. In nonsense this is not so. Again, in sense, to measure by speed is more realistic, not to say logical, than by errors, for in normal life one reads just so fast that one does not make errors. Illegibility manifests itself not by mistakes so much as by slow reading. On the other hand, these facts practically do not apply to nonsense or a foreign language, for which errors are a better index. If this is true, speed is not reliable here ; it may vary directly and not inversely with accuracy. If this, too, is true, an increase in errors alone might mean merely increased speed. Therefore, the final criterion in nonsense must be $\frac{\text{accuracy}}{\text{speed}}$.

Psychologically, speed is a dangerous measure because, as experimental evidence [1] shows, it is influenced by so many factors (some very powerful), both subjective and objective. Of the former, some are central, others peripheral, some constant, others variable ; by the latter are meant non-typographical factors. Hence, first, it will be practically impossible to control simultaneously *all* these influences; secondly, a given person's speed is unlikely to remain a faithful index exclusively of any one of these influences ; thirdly, moderate changes of a realistic sort in the typographical stimulus are extremely unlikely to produce reactions in speed directly proportional, or even significant.

The factors influencing speed are :

OBJECTIVE.

Nature of topic (frivolous, serious, tragic, comic, &c.).
Word length.
Illumination.

[1] See Romanes, Abell, Quantz, Beer, Prandtl, Pintner (*b*), Freeman, Richtmayer and Howes, Gray, C. T., Schmidt, Judd, O'Brien, Buswell (1922), and Hulten.

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SUBJECTIVE.

(a) *Central.*
Natural alertness.
Powers of comprehension.
Span of attention.
Imagery habits (auditory, visual, motor).

(b) *Peripheral.*
Visual acuity.
Eye-movement habits.
Vocalization (lip-movement).
Eye-voice span (in oral reading).

(c) *Constant.*
Early training.
Practice (not absolutely constant, but extremely persistent).

(d) *Variable.*
Age.
Health.
Fatigue (physical and mental).
Word familiarity.
Purpose of reading (amusement, general impression, critical, &c.).
Conscious attitude (deliberate control, interest, and, in experiments, desire to break own record, competitiveness, 'boredom').

PRACTICAL FACTORS, which will be discussed in § III, 2. b. i.

In spite of the objections, measurement by speed has frequently been adopted (much of the disqualifying evidence is comparatively recent), and this mistake was also made by the present writer. For these reasons, and because there may be other uses for speed, it is worth examining it further.

Speed can be measured in two ways: by the amount read in a given time, and by the time taken to read a given amount. Logically these are the same; experimentally, they are different.

If amount read is measured, the problem arises whether to calculate the number of inches, lines, words, or letters, whereas if time is measured, this problem is avoided. But measurement by time also entails difficulties. Reading for longer than a certain time (probably different for different people) involves fatigue, which is likely to influence speed. Now, a rapid reader is more likely to finish a passage before he has grown tired than a slow reader. The speed of the rapid reader, therefore, will not be influenced by fatigue, the slow reader's will. But it would seem possible[1] that a comparatively rapid reader in one set of circumstances may within limits be relatively slow in another. Hence the performances of different people, and of the same person on different occasions, will not be comparable. Theoretically, the rapid reader might tire sooner than the slow reader, and therefore their performances still be parallel, but the psychology of reading goes against this view.

These difficulties could be overcome by giving reading spells too short to reach the fatigue threshold, provided the latter were known approximately and no objections existed to spells so short.

[1] See Freeman, and O'Brien.

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In reading sense, people apparently cannot help making *some* errors. Now, if time is the criterion, and errors are committed in one passage, but not in another, an arbitrary equation is necessary between time and errors. But if amount read is measured, one has only to equate an amount read with no errors to one read with errors.

But what unit should be used for measuring amounts read? Inches, lines, or words, and fractions of these are impossible, since if the same number of inches or lines were read in a condensed as in an expanded face, these criteria would conceal that actually more print had been read in one than the other. And words vary in length, so that even if their number in each case were the same, the amount of print would probably differ. There remains the number of letters. But in sense every letter is not read, nor do those which are occur in any regular way on a page. Nevertheless, at any rate *a priori*, letters are probably the most accurate measure. Experimental results may suggest a combination or correlation of measurement by words and by letters.

As between time taken and amount read, an objective, quantitative decision can be reached only after experiment; till then the present writer favours amount read, with the unit the single letter.

To conclude the question of speed versus errors. Errors may be influenced in number, nature, and distribution. Number is much the most important here. We have no wide experimental knowledge of the influences governing the frequency of errors. Hence, and in the absence of evidence to the contrary, we can assume that errors are not so much influenced by the 'speed factors' (see pp. 31–2) as is speed.

Of the following two lists, the first contains all the factors which can at present be supposed to influence errors only, and both errors and speed; the second those which influence speed only.

*List* 1.

| | |
|---|---|
| SUBJECTIVE. | |
| 1. Association. | Central. |
| 2. Imagery habits. | |
| 3. Visual acuity. | Peripheral. |
| 4. Eye-voice span. | |
| 5. Knowledge of foreign languages. | Variable. |
| 6. Word familiarity (or rather novelty). | |
| 7. Health. | |
| 8. Fatigue. | |
| OBJECTIVE. | |
| 9. Illumination. | |

*List* 2.

| | |
|---|---|
| SUBJECTIVE. | |
| 1. Powers of comprehension. | Central. |
| 2. Natural alertness. | |
| 3. Vocalization. | Peripheral. |
| 4. Eye-movement habits. | |
| 5. Early training. | Constant. |
| 6. Practice. | |
| 7. Age. | Variable. |
| 8. Purpose of reading. | |
| 9. Conscious attitude. | |
| OBJECTIVE. | |
| 10. Nature of topic. | |
| 11. Word-length. | |

In List 1, factors 1, 2, and 4 are not practically controllable; the others are.

Associations are less important than may appear; for, although they may cause some errors, they may be presumed to be about equally numerous for all normal subjects, and their power is reduced to a minimum.

Imagery habits (auditory, visual, motor) influence only the nature of errors.



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In List 2, the effect of No. 6, Practice, upon errors (in contrast to speed) wears off rapidly, and in experiments can therefore be excluded.

Finally, then, the best *available* criterion is the number of errors. But it leaves unmeasured that element of legibility which consists in rapid reading, and it is inapplicable to sense material. There has emerged, therefore, no completely satisfactory solution to the main scientific problem of legibility.

### (d) *Procedure*

(i) *Loud or silent reading?* Theoretically, the answer to this query is 'silent'. There are various differences between the oral and silent processes, but silent reading is almost always meant, and forms practically the whole of adult reading in normal life. These differences, some of which have been discovered by comparatively recent experimentation,[1] may be classed under three heads: (1) the mental attitude, (2) the physical, and (3) the physiological.

(1) The general mental attitude is different. In silent reading attention moves freely, in oral it is constricted by articulation. In silent reading a high correlation apparently exists between speed and degree of comprehension, in oral a low correlation.

(2) In oral reading there are more head movements, and the time devoted by the eye to a line is more evenly distributed over the whole.

(3) In oral reading a factor appears which does not exist in silent reading, except in shadowy form with lip-readers, namely, the eye-voice span. The width of this span shows a high correlation with speed and with the point at which the voice has arrived in the sentence, a low correlation with the position in the line, and a negative correlation with the number of eye-fixations. In these last lie the main physiological differences. The fixations are longer and more numerous in oral reading (both Judd and Schmidt assert they occur on every word). Primarily, they are speech units, accommodated to the vocal apparatus, whereas in silent reading the fixations may fall anywhere, and are essentially perceptual units, dominated by the demands of recognition. But—and this seems to be the only resemblance between the physiological bases of loud and silent reading—there is always some, however little, suppressed articulation in silent reading, although apparently it can be considerably reduced. Further, there are many more *re*fixations in oral reading. In silent reading many are a sign of inferior comprehension, but in oral they are caused by there being actually more fixations, and the eye being ahead of the voice, and having to return now and then to aid and correct it. Articulation retards everything else; hence the range of individual variations of speed is narrower in oral than in silent reading.

In an experiment we cannot measure accurately the speed or errors of a subject who reads to himself. We know when and where he started and stopped, but not whether he skipped words or a sentence or a line, or returned upon the same line, and these mistakes would

[1] See Gray, C. T., Schmidt, Whipple and Curtis, Judd, McLeod, Buswell (1920), O'Brien, and Smith.

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alter his true speed of reading. Yet they cannot be ascertained, because the subject was either never conscious of them or has forgotten them. These difficulties apply especially to errors. The silent reader of nonsense either imagines he has read correctly or, if he suspects he has made an error, can hardly ever recall it.

Other attempts have been made to measure accuracy in silent reading (of sense), as is known to any one familiar with the literature on school reading-tests. Generally the subject has to read a passage silently, and is then asked conundrums about it, set missing-word- or picture-puzzles, or has to write out the passage from memory. All these tests involve memory or reasoning or both, and generally very arbitrary scoring methods. They measure, not merely accuracy of reading, but accuracy of understanding, remembering, and thinking.

In silent reading, then, neither accuracy nor the subject's general behaviour can be checked; in oral, that is audible reading, they both can. But the errors are unlikely to be the same as if the passage had been read silently. Auditory and motor influences will predominate where a passage is 'tongue-twisting', and articulation will tend throughout to produce tongue-mistakes which would not have occurred in silent reading, although the eye-mistakes, which would, may appear too. Refixations also can be avoided if the subject is told to read straight ahead. Even if there are more (and different) errors in oral than silent reading, these distinctions would presumably remain constant from type to type. Still, the oral and silent processes are not the same, and we shall be measuring the speed not of the eye, but of the tongue—in other words, the faster in terms of the slower. Better than this would be to measure speed in silent reading.

The relation between speed in silent and oral reading is given by Whipple and Curtis thus: a number of subjects read in various ways, their scores were ranked, and the orders for each method of reading correlated.

Correlation between normal rate loud and normal rate silent: +0·66. Probable error: 0·17.

Correlation between maximum rate loud and maximum rate silent: +0·65. Probable error: 0·18.

But for measuring accuracy loud reading must be used.

(ii) *Maximum or normal speed?* Normal speed is the more realistic, but maximum is more convenient experimentally. One has several normal speeds within a given range, but only one maximum. It is therefore easier to maintain one speed for a short time by reading at maximum than at normal. Besides, the direction of misjudgement by subjects trying to maintain normal speed would fluctuate and differ. Finally, it is easy to notice in ordinary reading other changes in one's speed due to fluctuating interest and comprehension. But one ignores these, reading consistently at maximum speed, and becomes less conscious of one's speed; hence the performance is more objective, and this is an advantage.

Whether reading at maximum speed distorts the true influence of objective legibility is not known, nor apparently is the effect of maximum speed on errors. Presumably it will increase their number,



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and therefore the data, but not affect their nature. Their distribution will be affected thus : it is harder to read accurately very fast than at one's own pace. The extra mistakes at maximum speed must tend, *ceteris paribus*, to occur first in the more illegible letters. Hence the difference between legible and illegible letters will tend to be exaggerated. The relative legibility of different type-faces, however, as measured by errors, will not be falsified.

A comparison of different readers' speeds will give the same result whether reading was at maximum or normal rate, according to Griffing and Franz ; and Quantz, who found a very high correlation, concluded that ' nearly the same forces determine both '. Whipple and Curtis found the following correlation coefficients :

Normal speed and maximum speed in silent reading : + 0·70. P.E. : 0·16.

Normal speed and maximum speed in oral reading : + 0·62. P.E. : 0·19.

But their figures for oral reading at maximum speed (what we propose) with silent reading at normal speed (the most realistic) are respectively + 0·42 and 0·25.

It seems unsafe, therefore, to measure speed, reading orally at maximum rate, but reasonable thus to measure errors. The mistake, however, was made in the present experiments.

(iii) *Length of exposure.* An instantaneous exposure involves an artificial setting and altered subjective reaction. The exposure must be a sample of realistic reading. It must last long enough to allow eye-movements and a change of line and to render negligible the influence of initial inertia (this can be assisted by suitable stimulation of the attention) ; it must be short enough to exclude fatigue, with which, though important, we are not yet concerned. Moreover, needlessly long exposures might produce confusion, and the whole method become experimentally unmanageable. To fit all requirements the exposure must be long enough for about one line of nonsense or two of sense to be read (the latter is read faster), but how long this is can be discovered only by experiment. In fact it is about four seconds.

### (e) *Classification of data*

In sense the number of letters read will be the main data and the number of errors minor data ; in nonsense it will be the reverse. The number of letters read in any exposure is taken to include *every* letter between the subject's first and last, whether they were read, misread, or omitted. For the number of errors is more important than the number of letters, and you cannot logically count as misread a letter not counted as read. On the other hand, this method counts as read a letter which was not read but omitted. But other errors as well as omissions will be made, and all misread letters must be treated the same. Any decision about this must be arbitrary, and since errors are more important than the number of letters, we will count an omission as one letter read and one mistake.

Now as to errors. Although with sense-material they are not to be the criterion of results, they will be noted, and if possible classified and counted. The same classification will be used to start with as

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in nonsense. This will be discussed below. Each word misread, no matter how, will be counted as one error. In sense, where one error can cause others, all systems of error-valuation break down logically at some point. This one is no more arbitrary and much simpler than many.

Here we must anticipate. It is useless to classify errors before knowing what sorts will be made. In practice, therefore, one must wait until a fair number of mistakes have been obtained from all subjects.

Even if concerned solely with the total of errors per type-face, we must decide what constitutes one error, which involves differentiating between various sorts. Several classifications have been used. The following comprise all those known to the present writer :

MESSMER, O. E. (1904). (Oral naming of isolated words in tachistoscopic experiments on the psychology of reading.)
- Visual.
- Articulatory.
- Thought.
- Grammar.

ROETHLEIN, B. E. (1912). (Oral naming of isolated letters and spelling of nonsense groups in experiments on legibility.)
- Combinations (e. g. lc read as k).
- Separations (e. g. k read as lc).
- Elisions (i. e. a sort of omission ; e. g. omitting i, j, t, r, v, or s when between ascenders or descenders).

GRAY, C. T. (1917). (Continuous oral reading in experiments on reading ability.)
- Omissions.
- Repetitions.
- Insertions.
- Mispronunciations.

MCLEOD, L. S. (1918). (Oral reading by children.)
- Mispronunciations { gross. / minor.
- Omissions.
- Insertions.
- Repetitions.
- Substitutions { ' involving little or no change of meaning '. / ' involving much change of meaning '. / ' which give no connected meaning '.

GRAY, W. S. (1919). (Oral reading by children.)
- Complete mispronunciations.
- Omissions.
- Substitutions.
- Repetitions.

These classifications, like all others of this material, are arbitrary. But two conditions every classification should fulfil. It should exactly cover all the data, but leaving no anomalies ; and it should be objective, that is, it should not prejudge.

A classification which was *a priori* faultless, but of which some classes remained always empty, would be bad. Further, it should never be in doubt to what class an error belongs. If it is, the experimenter has to decide which class is likeliest. In Messmer's classification there must be instances where he cannot *know* positively that an error was visual and not one of thought. He therefore *assumes* it was one or the other. In so doing he himself determines the relative frequency of this and that class of error, instead of letting the experimental stimulus.

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Roethlein's classification, though possibly suited to her own data, would seem incomplete and rather rough. But her first two classes avoid considerable difficulties (to be mentioned shortly). In the other classifications, insertions, omissions, and substitutions are, it is true, objective. But if 'insertion' is used, 'repetition' seems superfluous; the latter could be reduced to terms of the former. Again, mispronunciation seems a useless class, since every oral error might be termed such.

The classification provisionally suggested is omissions, insertions, substitutions, transpositions. One might argue that substitution really equals omission plus insertion, but this, if literally true, is psychologically false. The chief objection is that this classification too prejudges. The problem of prejudging is twofold: (1) one may sometimes be able only to guess at what really happened; (2) even if sure, one may be in doubt to which class an error belongs.

(1) A subject read as far as c in the nonsense group 'vreecsin', but read 'vrec' for 'vreec'. Now, did he never reach the printed c but substitute c for the second e (vrec for vree), or did he reach c but omit one of the e's (vrec for vre(e)c)? Both are quite common errors. But to choose what seems the likelier is to assume what is being examined, while to classify the mistake both ways is extremely cumbersome and hardly nearer the truth. In such cases it was taken that the subject reached the printed c and had omitted an e.

Again, Roethlein, who calls k read as lc a separation, would presumably call m read as nr the same. Our classification would either show n substituted for m and r inserted (the course actually taken), or r substituted for m and n inserted. Which really happened? Roethlein burkes the question; we prejudge it. But we procure consistency with the rest of the classification. For either n or r was inserted, but in another case n (or r) was inserted alone, without an accompanying substitution. Hence the substitution of n (or r) is counted as such in both cases by our method, but only in the second if we use 'separation'. Further, Roethlein apparently counts k read as lc one error, we, two. Hence the method of classifying affects the number of errors.

(2) The 'word' 'ushot' was read by one subject as 'ushto', by another as 'ustho', and a third as 'usho'. 'Ushot' read as 'ushto' is a transposition of o and t, and counts as two errors. 'ushot' read as 'ustho' is a transposition of ho and t, and counts as three errors. '*ushot*' read as '*tusho*' is a transposition of usho and t, and counts as five errors. Now, if 'ushot' had been completely misread, for instance as 'nabel', there would also have been five errors. But 'tusho' for 'ushot' is palpably a lesser error than 'nabel' for 'ushot'. Not to 'transpose' one letter with another, but to call it 'displaced', would avoid clumsy solutions of errors like this, but would alter the number of errors from five to one. Besides, displacement would also have to be used when adjacent letters were transposed; yet which one should then be called 'displaced'? The number of errors would not be affected, but their distribution would.

A simpler method would be to count every group not correctly read as one error. But in nonsense, where errors are due to inde-

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pendent causes, it would be extremely misleading to assign the same error-value to a group whether one of its letters was misread or all.

There are two further points about the method adopted. First, questions of classification have been discussed primarily for their influence on the number of errors. But there are other aspects and questions which affect the relative frequency of different sorts of error and the relative legibility of the letters of the alphabet. Experience shows that only moderate weight should be attached to one *sort* of error as compared with another, for it is here that the elusive psychological influences seem to obtrude least controllably. Nor can one always be sure what happened. For instance, in a composite error, it may be c that was substituted for e or that c was inserted. In the first case there is an increase in the number of substitutions and misread e's, in the second of insertions and misread c's. We know only that one mistake of some sort was made.

Secondly, it may be argued that the factors which affect the number of errors are less important than might appear. For, whatever classification is adopted, provided the same be used throughout, its inaccuracies will affect absolute results, but not the relative merits of different types. This argument ignores, however, the factor of individual differences. It assumes that the relative frequency of different sorts of error either is about the same for every one, or that whether it is or not does not affect the matter. Either would be extremely difficult to maintain rigidly. The argument further assumes that the relative frequency of different sorts of error remains constant for a given subject, even despite changes of type-face, but facts do not seem to bear this out. However, enough has been said to show that there are problems of classification which make it difficult to handle data without making them spurious.

### (f) *Subjects*

Subjects should be physically and mentally normal. They should be emmetropic and in good health. They should possess normal intelligence, be of adequate education, and accustomed to reading. Preferably (see p. 27) they should know no foreign languages, failing which all should know the same, each subject as well as another.

Javal argued that, since the perfect eye is so rare, print should be reformed to suit, and experiments conducted with people having various classes of pathological eyes, but this method did not recommend itself, at any rate for preliminary use, in this research, of which the main principles are normality and realism.

Although benefits such as fuller and more reliable introspective reports might accrue from employing subjects familiar with experimental psychology, it would seem desirable that they should not have such knowledge, and particularly so that they should know nothing about the experiments. Hence neither the experimenter nor his assistants should act as subjects. Several experimenters have, however, done so.

Should the inquiry be extensive or intensive? If it is extensive, most of the results will be deduced from broad statistical arguments based on probabilities and sampling. But we shall not gain very deep insight into the psychology of legibility and reading, and without

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such insight we may arrive at unsound conclusions by arguments statistically plausible but psychologically false. But, if to start with the inquiry is intensive, we are not deprived of statistical aid, and can examine, too, the psychological, that is, the least understood and perhaps most important aspect of legibility. We want to estimate and isolate the force of subjective individual differences. We want to discover how persistent, fluctuating, or evanescent are various reaction-tendencies in individuals, and how many and what sorts of non-typographical influences enter into a situation. These problems can best be attacked by observing a few, i. e. about half a dozen, normal subjects at a time over an extended period. If this is done the subjects must be the same from start to finish.

### (2) Practical

#### a. *Typographical*

Physical obstacles prevent absolutely the attainment of some of the most obvious theoretical desiderata. Suppose one is studying the effects of varying the gauge of a face, its extension, condensation, or thickness of limb. The design should be kept constant, as too the quality and colour of paper and ink, the interlineage, and so on. In practice one has to find a printer willing to assist in (for him) an undesirable task. Again, in practice one cannot have a face specially designed and cut, but must choose from catalogues. And when it comes to searching these, it is frequently found that a type, most suitable in every other respect, is not available in the required size, or is in modern but not in old style, or vice versa. Or it has abnormally long or short projectors, or certain peculiarities, such as an oblique bar to its e, or a fancy overlapping in its w. The result is that the faces finally chosen are mostly second, or even third or fourth preferences.

In the printing, too, are difficulties. Uneven and too heavy impression forming ribs in the paper which distort the letter-shape, inequalities in the intensity of the ink, and faulty, worn, or battered types, though each may seem trifling individually, together can change the look of a page as much as certain typographical factors proper. But to prevent all these defects absolutely is extremely difficult.

It may be thought that some of these difficulties can be solved by making enlargements, reductions, compressions, and extensions photographically. But this method raises objections. In its smaller sizes, the proportions of a face of given design are in practice altered. The counters and hair-lines are reduced less than in proportion lest they should disappear, the former by becoming filled in, the latter by becoming too fine to impress. Descenders, on the other hand, are more shortened in proportion than ascenders. The result is to make the proportions of large and small sizes look the same. For this reason, and because our eyes are accustomed to these illusions, the proportions of faces reduced photographically would *look* abnormal.

Again, suppose it were desired to study spacing and leading, and with the same faces as before. One could not by photographic means increase or decrease the vertical or lateral spacing without

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A subject is seen on the right, facing the opening, and the experimenter, hidden from him by the vertical screen, on the left of the photograph. The shutters are partly open. Two pointers (that on the top edge and that on the right edge of the opening) are visible. A scrap of white paper was placed behind the top one merely to make it more noticeable in the photograph. The pointers were set by manipulation of the two dials facing the experimenter. The lines of print are not distinguishable on the page exposed, in this photograph.

*To face p.* 41.

similarly changing the height or breadth of the letters. Hence, typographical methods would be necessary. But in testing other factors photography would already have been used, and the results by these two methods are not comparable. Hence, photography must be abandoned.

b. *Experimental*

(i) *Apparatus.* Dodge states that ' no psychological instrument is subject to greater modification in response to special experimental conditions than exposure apparatus ', and Whipple adds that ' in no other experiment are the results more evidently conditioned by the form of apparatus and type of procedure employed '.

The important difference between the instrument used and what are generally called tachistoscopes is that exposures in the latter are instantaneous and in the former varied between about 0·5 and 15 seconds. The apparatus consisted of two main parts : the exposure frame and the motor. The photograph shows most of the main features of the former. It was 22 in. × 19 in., and was inclined to the horizontal at an angle of 30 degrees. The opening was 6 in. × 9 in. This contained the test-sheet, which lay on a trap-door, which opened downwards. The frame was of fairly light brown stained wood, but was later covered by brown cardboard. The shutters were of a light sage-green card. This surface was too glossy, but was subsequently made matt. Each shutter moved on a pivot. One was at the right top, the other at the left bottom corner. The shutters were operated by electro-magnets, and the current passed through the circuit of a pendulum mechanism—a variety of Brody clock. The clock circuit occupied 15 seconds, and the shutters could be opened for any period less than this. For these tests they were open 4 seconds, remained closed for 11, opened again for 4, and so on. While they were closed, and leaving the clock still working, the tachistoscope circuit could be temporarily cut out and the interval prolonged. The clock stood in a cupboard and was inaudible to subjects.

The starting-point was altered from one line and part of a line to another on an octavo page of print at every exposure. A bracket in red ink was marked on the left of the starting word, each sheet having only one mark. Since this was invisible till the shutters parted, guides were provided in front of the shutters (which were $\frac{1}{2}$ in. in front of the sheet, i. e. about 8 per cent. of the distance from the subject's eye). Two wire rods, moved by hand, lay along adjacent edges of the opening, their tips only projecting over the margins of the sheet. The subject fixated the spot where the pointers would have intersected, i. e. directly above the bracket. Later these rods were superseded by four flat spear-shaped pointers of aluminium foil, painted a dead black. These were moved with greater ease and accuracy by a concealed system of pulleys.

After a little practice subjects were able to pick up their starting-point with astonishing rapidity and ease. Other devices for fixation marks, mechanically superior, were rejected because they entailed more artificial settings (head-grips, ground-glass screens in tunnels, &c.).

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The screen was erected (at the same time as the change of pointers, and only after some time) to hide the experimenter from the subject and prevent the latter from being distracted by the manipulation of the apparatus and the note-taking.

In eleven seconds the experimenter had to note on a duplicate sheet where the subject started and stopped, the fullest details of every error, and any introspections of value. He had to open and close the trap-door to change the sheet, read from another sheet the figures giving the positions of the pointers and set these. When errors or introspections were intricate or lengthy (they frequently were), it was impossible to complete everything in the time. On these occasions the experimenter cut out the current till he was ready. But he had no notion at what moment in the clock's circuit he had reconnected the tachistoscope and could not tell, within fifteen seconds, how soon the shutters would open. This delay imposed an irregular strain upon the subject's accommodation muscles and attention. He might be caught in varying degrees of mental and ocular readiness. These conditions influenced the amount read and errors. A circuit containing a bell was therefore added (at the same time as the screen, &c.), which was cut out and reintroduced automatically with the clock circuit. The bell rang once, two seconds before the shutters opened. This interval was found to be the most suitable, and the sound was killed almost directly, so that the subject was not distracted.

Wundt lays down seven conditions for a good tachistoscope, and Dodge adds three more. Of these the following are applicable here.

'The exposure of all parts of the field should be simultaneous (i. e. only subjectively), or so nearly so that there are no noticeable time-differences in the illumination of the various regions' (Wundt).

This condition was not fulfilled, but the harm was due less to differences in illumination than in visibility. Words on the diagonal along which the shutters met were revealed sooner and covered later, and some perceptibly so, than any others. And if, when the shutters began to close, the subject was reading in the field of the left shutter, his eye and the shutter would move in the same direction. Hence the faster he read, the longer succeeding words remained in view. Conversely, with the right shutter, the sooner would they disappear. This lag of the shutters influenced the amount read, and probably errors, for subjects could sense a delay, might grow flurried, and were then more inclined to misread. Finally, the shutters often rebounded a little after closing. If a subject was reading in the gap thus formed, he might read on, whether consciously or not, or, as sometimes, uncertain. This rebound was never overcome. To increase the overlap meant making the shutters heavier and their action still slower. However, all these defects were counteracted to a great extent by distributing the starting-points evenly over the whole page, so that unduly short exposures should cancel unduly long.

'Persistent after-images must be avoided' (Wundt).

This was fulfilled, if subjects' reports may be relied upon. The wall facing them was cream coloured, but they might move their heads during the intervals and look anywhere except towards the light-source.

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'A ready signal must be given at an appropriate time before the exposure' (Wundt).

This condition was properly fulfilled only after the bell was introduced.

'The exposure should be noiseless and free from distraction' (Dodge).

While the shutters were open there was no noise, and after the screen was erected no distraction. But the movement of the shutters made two clicks in rapid succession about as loud as a gentle hand-clap. But subjects soon came not to notice this, and a large number of exposures was given.

Two further conditions will be considered in the next subsection (ii). The only serious defects were the lag and rebound of the shutters.

The nature of this apparatus bears on the choice of a criterion. The defects influenced neither the nature nor distribution of errors, nor their number except in proportion to the amount read, which did not matter. But the amount read per exposure was subject to various influences arising from the shutter action, the device for fixating, and to the fact that subjects gathered speed most quickly when starting from the first word of the page, less quickly from the first word of any other line, and least from the last word of a line. But this influence, too, could be largely mitigated by suitable distribution of starting-points over the page and by enough exposures. Still, one is only relying on probabilities; the defects may continue to bias unperceived. The apparatus is more suitable for tests by accuracy than by speed.

(ii) *Illumination.* Illumination throughout was artificial. Daylight cannot be controlled, the other can. Four 100-watt bulbs, covered by semi-reflectors, hung one in each quarter of the room, which was 13 ft. × 14 ft., and about 15 ft. high. The light was evenly diffused and without glare, and, except in one series of tests, was theoretically constant at 4·5 foot-candles on the surface of the test sheet. No shadows fell upon the sheet, at least never on the part being read. The illumination was regulated by a rheostat and measured (before every session) by a lumeter made by Messrs. Everett, Edgecumbe & Co. Two adjacent surfaces, one lit by a calibrated lamp, the other by the experimental light-sources, had to be matched in brightness. The current was from a 2-volt accumulator. This method of photometry was chosen because it was simple and rapid.

Now, first, owing to load-variations the illumination in the room could vary, within limits (which were wider, the slower the change), without being noticed. Secondly, the building's installation was such that the lights in the room were liable to flicker uncontrollably and without warning. Thirdly, the eye might err in matching the brightnesses of the lumeter surfaces. Fourthly, after some time, the lumeter lamp deteriorated, and, if used after this deterioration had set in, the light calculated to be correct would really be too strong. Two lumeters were used, as a check, but errors must have been made. Fifthly, the current for the lumeter had to remain between 1·9 and 2 volts. Now, a variation of 1 per cent. in the strength of the cell would cause one of 5 per cent. in that of the lumeter-light.

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Further, 4·5 foot-candles *may* (see e. g. Luckiesh, Taylor, and Sinden) lie within that range of illuminations which, if changed, produce a disproportionately large effect on visual tasks. Hence, a quite small error in reading the voltmeter might influence results. But even if not, all these causes of error operating together probably would.

Javal says that the legibility of letters composed solely of lines uniformly thick (such a face was tested here) is determined in the same way as its visibility, i. e. it varies directly with the illumination. If he is right, these questions of illumination, though not arising in theory, are important practically.

To return to the conditions postponed from p. 43.

'Retinal adaptation must be favourable, and there must be no sudden transitions from dark to light' (Wundt).

Subjects had 5 minutes for eye-adaptation when the light was 4·5 foot-candles, and 20 minutes when it was 1 foot-candle. Sudden transitions from dark to light were avoided.

'The relative illumination of the pre-exposure, exposure, and post-exposure fields should be capable of experimental modification' (Dodge).

This could be done (with the rheostat), but only rather clumsily. In practice the illumination was kept constant, accidents apart.

Whipple argues that to know the illumination of the exposure-field without the pre- and post-exposure fields' is useless, since the last two fields, if bright, protract, if dark, cut short the 'subjective exposure'. To make the durations of the objective and subjective exposures coincide, he recommends black pre- and post-exposure fields, or at least a post-exposure field not brighter than the exposure field. In these tests the brightness of the pre- and post-exposure fields was about 75 per cent. of the exposure field's. The post-exposure field's could vary between 50 and 100 per cent. according to where a subject looked, which was anywhere but towards the light-source. Black shutters with an exposure field of alternate black and white lines would have increased dazzle.

(iii) *Subjects.* It is not easy to find four people with all the enumerated qualifications, willing and able to give a fair amount of their leisure free, regularly, and for weeks at a stretch, who can guarantee to remain accessible possibly for several years. The earliest experiment-series were undertaken each with different subjects, seventeen in all. They were students and others who could give their services for but a short time, and naturally could not guarantee their place of residence against change, and all had some knowledge of experimental psychology, such people being precisely the most accessible. It was not at first realized that this work would be hampered by so many variables, psychological, physiological, and mechanical, unable to be either excluded, controlled, or even measured. Yet these experiments, though failures, had some value as a field for psychological observation.

In October 1924, paid subjects were engaged to act permanently. They will be referred to as Nos. 19, 20, 21, and 22 (No. 19 was a female subject). The following are the most important facts about them.

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| Subject No. . | 19. | 20. | 21. | 22. |
|---|---|---|---|---|
| Age (Oct. 1924) | 18 years. | 23 years. | 21 years. | 19 years. |
| Occupation . | Learning shorthand and typing. | Choir-master. | Library Asst. | Library Asst. |
| Eye-sight . | R.V. 5 letters out of 8 of 6/5ths. L.V. 3 letters out of 8 of 6/5ths. Not improved with glasses, though reason to think she has minute amount of astigmatism, probably less than 0·25 cyl. axis. vertical. Had been wearing + 0·5 D. sph. for convenience in fine jewellery work. | R.V. 6/5ths, J. 1. L.V. 6/5ths, Reads J. 1. Has a very low degree of hypermetropia, + 0·5 D. sph., which is of no importance. | R.V. 6/5ths (1 letter wrong). L.V. 6/5ths (3 letters wrong). Reads J. 1 (diamond type) with each eye. No refractive error. | R.V. 6/9ths. Slight myopia (− 0·75 sph. gives 6/6ths). L.V. 6/6ths (2 errors). No refractive error. Reads J. 1 easily with each eye. |
| Foreign languages. | Knows a very little Latin and French. | Knows a very little French. | Knows a very little French. | Can read a little French well enough for pleasure. Had learned Latin for 9 months. |

No subject had any knowledge of psychology, but each was informed that the object of the experiments was to discover the relative legibility of different type-faces. They were never given the least information as to the results of their own or each other's performances. All were previously unknown to the experimenter and one another, except Nos. 21 and 22, who knew each other.

Subjects attended regularly, and were paid weekly. None wore glasses during the tests. Their eyesight was tested by a surgeon, Mr. Arthur Cooke, of Grove Lodge, Cambridge, to whom the nature of the experiments had been explained, and to whom my best thanks are due. His reports are quoted verbatim.

The qualifications of these permanent subjects, then, did not fall seriously short of theoretical requirements.

(iv) *Procedure* (*general*). All experiments, except Series 9 and 10, were conducted as follows, after two or three days of practice. The subject started to read aloud as fast as he could directly the shutters opened and until they closed, reporting what he saw last even if he thought it was a guess, and however incomplete. Forty exposures were given at a session, which lasted about fifteen minutes. The results of an exposure depended partly on the position of the starting-point on the page, partly on whether a change of line was involved, and on the nature and amount of punctuation. A session of about forty exposures contained enough to allow undesirable influences to cancel out, so far as this was possible, and was short enough to preclude fatigue. The figure 40 was convenient arithmetically.

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In every series but Nos. 9 and 10 vowelless nonsense (while used) was presented first, ' vowelled ' next, and sense last. This order was preferable to the reverse, because it prevented recognition in the second or third parts of anything read in the first or second.

The whole of one type was worked through thus, then the next, and so on. This was a weakness in the general character of the experiments. If practice or accustomedness had any influence, this method aggravated rather than counteracted it, since more practice would have preceded the last face tested than the first. The only solution would have been to test all types at every session, and revolve their order at each (subjects attended twice daily) until every type had been tested once in every position. But this seemed impracticable without making a session too long (about $2\frac{1}{2}$ hours) or contain too few exposures per type. Some such solution, however, could probably be produced.

The earliest experiment-series were the longest. Their results showed that it was safe to reduce the number of exposures per type, and, in later series, this was done.

In vowelless nonsense, the position of the starting-point was moved every exposure towards the right, in ' vowelled ' nonsense towards the left, and in both, line by line, to the foot of the page. In sense material, either method would have affected a subject cumulatively, since in each exposure he would have been helped by the context of all preceding ones. In sense, therefore, the starting-point was moved to right and left, up and down the page. Results and subjects' reports show that this method succeeded.

The procedure adopted in experiment-series 9 and 10 is discussed in the next section (IV).

## IV. THE EXPERIMENTS

### 1. Series A, B, C, and D

These series were intended to compare (1) the effect of a normal with a low illumination on the reading performance, and (2) the difference in the legibility of the three standard styles : Old Style, Old Face, and Modern Face. Since different subjects acted in each series, these experiments must fail in their chief purpose, but comparisons between subjects in a given series, and certain absolute results still hold.

Throughout these and all later series the quality and colour of paper and ink remained unchanged. The former, technically known as ' Double Crown Basingwork Parchment Quad Foolscap 80–516 ', was a matt white, and the ink a dead black. In series A–D the type body-size was Long Primer, and there were 48 lines to a page. In series A and B the face was Lanston Monotype Old Style No. 2, in series C, L. M. Imprint Old Face No. 101, and in D, L. M. Modern Extended No. 7.

Unsuccessful attempts were made to calculate the relative legibility of the letters of the alphabet. This could be done accurately only by counting the number of times each letter of the alphabet was read by each subject, and dividing this figure into the number of his

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errors. As it was often uncertain which letter had been misread ; as each subject read several tens of thousands of letters in every series ; as the labour would have been enormous, and the result not the main purpose of this work, the attempt was abandoned after series A and B.

In them also unsuccessful attempts were made to examine the influence of punctuation. Subjects jotted it down without looking, as they read, but sometimes preferred to use their memory. The first method was difficult, and distracted the attention ; the second probably did likewise and was unreliable. Moreover, the text could not be arranged scientifically for testing punctuation and differences of face at the same time.

Eyesight was tested only roughly for astigmatism and acuity, and subjects varied considerably. The number of exposures was reduced from 5,000 in Series A (2,000 in each sort of nonsense, and 1,000 in sense, divided among four subjects) to 2,500 in B, and 2,000 in C and D.

### 2. Series 1–8

The paid subjects, Nos. 19, 20, 21, and 22, were now introduced, and at the same time practical considerations made it advisable to change the type body-size from Long Primer which gave 48 lines per page to 10-point which gave 47.

The purpose of Series 1–8 was (i) to re-test in better controlled conditions the three standard styles used in Series A, C, and D, and (ii) to test in conjunction with (i) the comparative legibility of five sorts of face, each embodying a distinct and an important quality, viz :

1. Lateral extension of face.
2. Lateral compression of face.
3. Uniform thickness of limb.
4. Uniform thinness of limb.
5. Absence of serifs.

The types chosen embodied these qualities in as extreme degrees as practical conditions (see p. 40) allowed. Table No. 7 presents the main dimensions of each face. The bracketed numbers in Column I give the order in which the faces were tested. It proved impracticable to obtain types 4–7 all in Old Style, or all in Modern, so one pair of comparable faces (Nos. 4 and 5, the narrow and the broad) was printed in Old Style, the other pair (the thick-limbed and the thin) in Modern.

Each subject gave 5 sessions, i.e. 200 exposures, of nonsense material with vowels, and 3 sessions, or 120 exposures, of sense. The vowelless nonsense was abandoned because it was the most artificial part of the experiment, could never give complete results, and because the economy seemed justified by the similarity between the results of vowelless and ' vowelled ' nonsense in Series A–D. The tests on each type occupied four days.

After the last exposure in each session of sense material, ten more exposures were given of sense printed in the ' standard ' type, No. 1. Series A–D had shown that a subject's speed fluctuated considerably

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TABLE 7

| *Column I.* *Type-face No. and designation* | *Column II.* *a–z length (in 10-pt. ems).* | *Column III.* *Gauge (l.c.)* [1] *(in hundredths of a mm.).* | *Column IV.* *Thickness of mainstroke (in hundredths of a mm.).* | *Column V.* *Thickness of hair-line (in hundredths of a mm.).* | *Column VI.* *'Coefficient of contrast' (i. e. column IV / column V).* | *Column VII.* *Length of serif projecting from mainstroke (in hundredths of a mm.).* | *Column VIII.* *Width of 'eye-piece' in* c *(in hundredths of a mm.).* | *Column IX.* *Width of 'eye-piece' in* e *(in hundredths of a mm.).* |
|---|---|---|---|---|---|---|---|---|
| (1) Lanston Monotype. Old Style No. 2 | 13 (shade under) | 152·2 | 27·7 | 8·1 | 3·42 [2] | 32·3 | 64·6 | 43·1 |
| (2) L. M. Modern Extended No. 7 | 13 (s. u.) | 152·2 | 28·3 | 10·8 | 2·62 | 36·9 | 20 | 15·4 |
| (3) L. M. Imprint Old Face No. 101 | 13 (s. u.) | 152·2 | 32·3 | 16·9 | 1·91 | 21·5 | 46·1 | 38·5 |
| (4) L. M. Modern Condensed No. 39 | 11¼ | 157·6 | 32·3 | 9·3 | 3·47 | 30·8 | 24·6 | 18·5 |
| (5) Caslon. Modern Series No. 23 | 13 (s. u.) | 152·2 | 27·7 | 9·2 | 3·01 | 33·8 | 29·2 | 20 |
| (6) L. M. Old Style Antique No. 161 | 13¾ | 175·3 | 40 | 29·2 | 1·37 | 23·1 | 76·9 | 44·6 |
| (7) L. M. Cushing Series No. 17 | 12 | 156·9 | 26·1 | 21·5 | 1·21 | 23·1 | 56·9 | 27·7 |
| (8) Stephenson and Blake. Lining Grotesque Series No. 10 | 14 | 166·1 | 30·8 | 20 | 1·54 | nil | 35·4 | 15·4 |

[1] The gauge measured was that of the lower-case i.
[2] i. e. entire absence of contrast would be denoted by unity.

every day even with the same type, although the influences determining speed were not properly understood. The last ten exposures in Old Style were intended as a check upon each variable type. If the amount read in the standard varied as widely as in the variable, this was to be evidence that the variations in the latter were not due to differences in legibility.

The chief results of Series 1–8 are contained in Tables 8–11.

### *Part* 1. *Nonsense material*

TABLE 8

*Average number of errors made per subject in each type-face in respect of each (lower-case) letter of the alphabet*

| *Type No.* | a | b | c | d | e | f | g | h | i | j | k | l | m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | 4·25 | 5·75 | 5·75 | 30·25 | 5·75 | 2·75 | 13 | 15·5 | — | 1·75 | 10·75 | 5·5 |
| 2 | 31·75 | 7·75 | 17·5 | 11·25 | 51·75 | 7·5 | 7·75 | 15·5 | 26·25 | — | 1·75 | 18 | 10·75 |
| 3 | 26·5 | 6·25 | 13·5 | 10·75 | 44·5 | 7·5 | 4·25 | 16·5 | 34·5 | 2·25 | 0·25 | 15·25 | 8·5 |
| 4 | 23·5 | 7 | 22 | 17·25 | 49·75 | 7·75 | 9 | 19·75 | 35·5 | 2 | 2 | 23·25 | 8·75 |
| 5 | 29·25 | 10·25 | 21·25 | 15·5 | 51 | 11·5 | 6·5 | 22 | 40·5 | 0·75 | 1 | 20·5 | 13 |
| 6 | 27 | 3·75 | 13·25 | 12·25 | 48·25 | 5 | 7·5 | 16·25 | 33·5 | 2 | 1·25 | 17 | 12·75 |
| 7 | 21·75 | 6·5 | 20·5 | 13·25 | 48·25 | 7·25 | 3·75 | 19·25 | 30·25 | 2·25 | 2 | 12·75 | 12·75 |
| 8 | 25·5 | 4·25 | 7·5 | 10 | 38·5 | 4·5 | 3 | 21·5 | 25 | 0·5 | 2 | 17 | 8·25 |

| *Type No.* | n | o | p | q | r | s | t | u | v | w | x | y | z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25·25 | 14·5 | 6 | 0·75 | 10·25 | 15·5 | 19·5 | 9·5 | 3·75 | 3·75 | 0·5 | 5 | — |
| 2 | 33·25 | 30 | 8 | 1 | 23·5 | 31 | 22·75 | 15·75 | 2·25 | 7 | 2·5 | 8 | 0·25 |
| 3 | 35·75 | 35·25 | 8·25 | — | 23·25 | 21·5 | 29·5 | 12·75 | 5 | 4·5 | 1 | 4·25 | — |
| 4 | 44 | 30·75 | 10·75 | 0·5 | 25 | 23·5 | 29 | 15·25 | 4 | 4·75 | 0·75 | 6·5 | 0·25 |
| 5 | 44 | 37·75 | 7 | 0·75 | 21 | 23·5 | 33·5 | 16·75 | 2 | 8·75 | 1·75 | 4·5 | — |
| 6 | 46 | 29·25 | 10·25 | — | 19·5 | 22·5 | 27·75 | 12 | 2·75 | 7·25 | 1·5 | 4·75 | 0·25 |
| 7 | 40 | 31·75 | 8·25 | — | 27·75 | 25·5 | 34·75 | 12·5 | 5·25 | 7·25 | 0·5 | 3·25 | — |
| 8 | 29·25 | 24·25 | 5·5 | — | 22·75 | 16·5 | 23·25 | 13 | 3·75 | 4·5 | 0·5 | 4·75 | — |

Nothing can be deduced from these figures about the relative legibility of different letters, because some letters occurred more commonly than others. And even comparisons between the legibility of the same letter in different types must be drawn with caution, since the number of errors varies with the amount read, and, first, this varied from subject to subject, and secondly, it is not known how many a's, b's, c's, &c. were read by each subject in any type. One can only say that in each type the relative frequency of occurrence of every letter was *about* the same as in every other type.

Type 1 shows fewer errors than any other in eighteen letters, the other eight (b, f, g, k, p, q, v, y) being among the uncommonest. Type 8 shows next fewest, or fewer, in seventeen letters. Among the other types no constant relations are maintained throughout the alphabet. For many letters the differences are so small that, even if significant, they are of little importance. No table of errors in capitals is given because in all eight series only about half a dozen errors were made. Compare now the results of individual subjects.



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## Table 9

*Average number of errors made per 100 letters read in each type*

| Type No. | Subject 19. Errors per 100 letters. | M.V. | Subject 20. Errors per 100 letters. | M.V. | Subject 21. Errors per 100 letters. | M.V. | Subject 22. Errors per 100 letters. | M.V. | Average.[1] Actual. | As percentages of No. 1. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3·6 | 0·52 | 4·6 | 0·48 | 3·5 | 0·88 | 1·4 | 0·20 | 3·04 | 100 |
| 2 | 6·5 | 0·82 | 5·7 | 0·42 | 5·8 | 0·30 | 2·2 | 0·32 | 4·66 | 153 |
| 3 | 5·3 | 1·14 | 5·4 | 0·66 | 4·9 | 1·12 | 1·9 | 0·36 | 4·36 | 143 |
| 4 | 8·1 | 1·70 | 7·1 | 0·44 | 4·8 | 0·60 | 2·0 | 0·60 | 5·16 | 170 |
| 5 | 9·2 | 0·46 | 7·8 | 0·66 | 4·2 | 0·76 | 2·1 | 0·24 | 5·18 | 170 |
| 6 | 6·8 | 0·34 | 7·1 | 0·60 | 3·6 | 0·36 | 1·8 | 0·36 | 4·46 | 146 |
| 7 | 7·0 | 0·94 | 7·3 | 0·36 | 3·7 | 0·36 | 2·7 | 0·58 | 4·52 | 149 |
| 8 | 5·9 | 0·76 | 4·5 | 1·60 | 2·5 | 0·70 | 1·9 | 0·36 | 3·40 | 118 |

Judging from the mean variations (being means of series of 5) the figures for the errors are significant.

[1] Calculated from same figures as were those of each subject. This is the case with regard to the averages in all the following tables.

## Table 10

*Comparative legibility of Types 1–8 in descending order of legibility*

| Order. | Subject 19. | Subject 20. | Subject 21. | Subject 22. | Average. | | As percentages of No. 1. | Difference per cent. (of lower figure) between successive types. |
|---|---|---|---|---|---|---|---|---|
| 1st | Type No. 1 | Type No. 8 | Type No. 8 | Type No. 1 | Type No. 1 | Standard Old Style | 100 | — |
| 2nd | ,, 3 | ,, 1 | ,, 1 | ,, 6 | ,, 8 | Sanserif | 118 | 18 |
| 3rd | ,, 8 | ,, 3 | ,, 6 | ,, 3 | ,, 3 | Standard Modern Style | 143 | 30 |
| 4th | ,, 2 | ,, 2 | ,, 7 | ,, 8 | ,, 6 | Thick | 146 | 2 |
| 5th | ,, 6 | ,, 4 | ,, 5 | ,, 4 | ,, 7 | Thin | 149 | 2 |
| 6th | ,, 7 | ,, 6 | ,, 4 | ,, 5 | ,, 2 | Standard Old Face | 153 | 3 |
| 7th | ,, 4 | ,, 7 | ,, 3 | ,, 2 | ,, 4 | Narrow | 170 | 10 |
| 8th | ,, 5 | ,, 5 | ,, 2 | ,, 7 | ,, 5 | Broad | 170 | 0 |

TABLE 11

*Showing the relations of the types when ranked according to various (lower-case) dimensions*

| *Type No.* | *a–z length.* | *Gauge.* | *Thickness of main-stroke.* | *Thickness of hair-line.* | *Contrast.* | *Length of serif.* | *Width of eye-piece in* c. | *Width of eye-piece in* e. |
|---|---|---|---|---|---|---|---|---|
| 1 | Equal 3rd | Equal 5th | Equal 6th | 8th | 2nd | 5th | 2nd | 2nd |
| 2 | Equal 3rd | Equal 5th | 5th | 5th | 4th | 7th | 8th | Equal 7th |
| 3 | Equal 3rd | Equal 5th | Equal 2nd | 4th | 5th | 1st | 4th | 3rd |
| 4 | 8th | 3rd | Equal 2nd | Equal 6th | 1st | 4th | 7th | 6th |
| 5 | Equal 3rd | Equal 5th | Equal 6th | Equal 6th | 3rd | 6th | 6th | 5th |
| 6 | 2nd | 1st | 1st | 1st | 7th | Equal 2nd | 1st | 1st |
| 7 | 7th | 4th | 8th | 2nd | 8th | Equal 2nd | 3rd | 4th |
| 8 | 1st | 2nd | 4th | 3rd | 6th | 8th | 5th | Equal 7th |



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The coefficients of correlation between subjects were as follows :

| | |
|---|---|
| Between Subject 19 and 20 . . . . | +0·91 |
| „ „ 19 „ 21 . . . . | +0·31 |
| „ „ 19 „ 22 . . . . | +0·62 |
| „ „ 20 „ 21 . . . . | +0·33 |
| „ „ 20 „ 22 . . . . | +0·60 |
| „ „ 21 „ 22 . . . . | +0·53 |

The coefficient of correlation between the legibility order of the eight types as given in Table 10, and their

| | |
|---|---|
| a–z length . . . . . | was +0·58 |
| gauge . . . . . | „ +0·12 |
| thickness of main-stroke . . . . | „ +0·11 |
| thickness of hair-line . . . . . | „ +0·14 |
| contrast . . . . . | „ −0·28 |
| length of serif . . . . . | „ −0·50 |
| width of eye-piece of c . . . . | „ +0·65 |
| width of eye-piece of e . . . . | „ +0·42 |

There is considerable agreement among the subjects, as shown in the graph opposite. The disagreement is found chiefly in respect of (*a*) types 4 and 5, i.e. the least legible (Roethlein found the same), and (*b*) Subject 21, who alone gives non-significant correlations.

Turning now to the average of all subjects :

(i) Type 1, the standard Old Style, is best, being 18 per cent. better than the next, and 70 per cent. than the worst. The best is the type which was tested first ; it is also the most ordinary. On the other hand, the next best was tested last and is one of the most uncommon. Moreover, the three standard styles (Types 1, 2, and 3) were so alike that they were frequently confused by lay eyes, yet Type 3 is 43 per cent. less legible than Type 1, and Type 2, 7 per cent. less than Type 3 ; nor do the three come together (they are 1st, 3rd, and 6th). The graph also shows some of the closest agreement between the subjects in these types.

(ii) Type 8, the Sanserif, is second best, being 18 per cent. less legible than Type 1. The gauge of Type 8 was the second largest, being 9 per cent. greater than Type 1's, and perhaps the type was thus unfairly helped. Its relative legibility agrees with Roethlein's results, but disagrees with Legros' and Grant's.

(iii) The biggest difference between any type and the next is between No. 8 and the Modern Style. The latter is 30 per cent. less legible than the former.

(iv) There is only 2 per cent. difference between the thick type and the thin.

(v) There is no difference between the compressed and the extended.

TABLE 12

| *Relative positions of the* | *Subject No.* 19. | *Subject No.* 20. | *Subject No.* 21. | *Subject No.* 22. | *Average.* |
|---|---|---|---|---|---|
| thick face and thin face . . | 5th<br>6th | Equal 5th<br>7th | 3rd<br>4th | 2nd<br>8th | 4th<br>5th |
| narrow face and broad face . . | 7th<br>8th | Equal 5th<br>8th | 6th<br>5th | 5th<br>6th | 7th<br>7th |
| 3 standard styles : Nos. 1, 3, and 2 | 1st<br>Equal 2nd<br>4th | 2nd<br>3rd<br>4th | 2nd<br>7th<br>8th | 1st<br>Equal 3rd<br>7th | 1st<br>3rd<br>6th |

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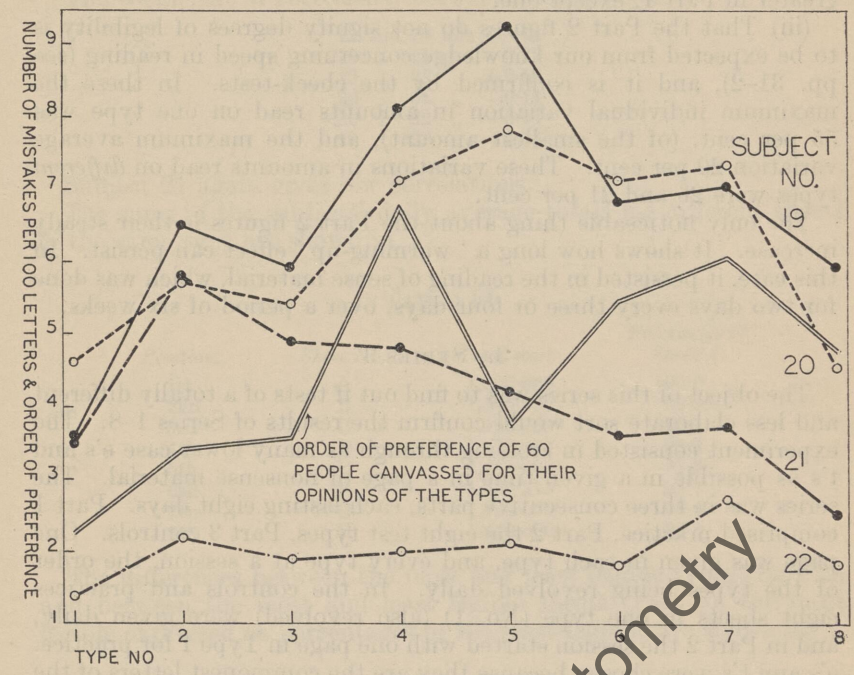
This negligible difference in legibility between types of opposite kinds is consistent with the fact that the most legible type is of a kind which stands midway between them.

(vi) The influence of the various dimensions of the faces is obscure.

The coefficient for the a–z length contains less force than appears, because four out of eight faces had the same length. The low coefficients for thickness of mainstroke, and of hair-line are in keeping with the result that there is no difference between the thick type and the thin.

The high coefficient for the eye-piece of c would seem unlikely to




signify any very important influence, seeing that c is so uncommon—it accounts for only about 3 per cent. of all letters on an average page.

The influence of the length of serif appears to conform with the general view except for the sanserif.

The correlation for the degree of contrast is very slight, but it is negative, which one would expect, and accords also with the general view.

*Part 2. Sense material*

The total number of letters read in each type was as follows :

| | | | | |
|---|---|---|---|---|
| In Type 1. | 3,583, | expressed as a percentage of Type 1 | . . . | 100 |
| 2. | 3,625, | ,, ,, ,, | . . . | 101·2 |
| 3. | 3,651, | ,, ,, ,, | . . . | 101·9 |
| 4. | 3,738, | ,, ,, ,, | . . . | 104·3 |
| 5. | 3,844, | ,, ,, ,, | . . . | 107·3 |
| 6. | 3,932, | ,, ,, ,, | . . . | 109·1 |
| 7. | 3,866, | ,, ,, ,, | . . . | 107·6 |
| 8. | 3,941, | ,, ,, ,, | . . . | 110 |

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If these figures are to corroborate results of Part 1, then (i) the types with the largest totals of errors in Part 1 should have the smallest totals of letters read in Part 2, and (ii) the relations of the intervals between the members of one series should be about the same as in the other.

(i) It is clear on inspection that there is practically no correspondence between the results of the two Parts, and the coefficient of correlation is −0·03.

(ii) In Part 1 the difference between the best and worst types is 70 per cent., in Part 2, 10 per cent. All the other differences are greater in Part 1, except one.

(iii) That the Part 2 figures do not signify degrees of legibility is to be expected from our knowledge concerning speed in reading (see pp. 31–2), and it is confirmed by the check-tests. In these the maximum individual variation in amounts read on one type was 55 per cent. (of the smallest amount), and the maximum average variation 20 per cent. These variations in amounts read on *different* types were 26 and 21 per cent.

The only noticeable thing about the Part 2 figures is their steady increase. It shows how long a ' warming-up ' effect can persist. In this case, it persisted in the reading of sense material, which was done for two days every three or four days, over a period of six weeks.

### 3. Series 9

The object of this series was to find out if tests of a totally different and less elaborate sort would confirm the results of Series 1–8. The experiment consisted in crossing through as many lower case e's and t's as possible in a given time in a page of nonsense material. The series was in three consecutive parts, each lasting eight days. Part 1 comprised practice, Part 2 the eight test types, Part 3 controls. One page was given in each type, and every type at a session, the order of the types being revolved daily. In the controls and practices eight sheets in one type (No. 1) (also revolved) were given daily, and in Part 2 the session started with one page in Type 1 for practice. e's and t's were chosen because they are the commonest letters of the alphabet. There were no e's and t's adjacent, upper-case E's and T's, or combinations of th, the, tt, or ee, except in a few instances where these combinations were inserted purposely. The e's and t's, spread evenly over the lines, were in the proportions of 12·3 and 9·6 per 100 letters (=1·3:1) in every sheet and type. These were the averages of twenty pages used in Series 1–8, and are nearly the same as those obtainable from Legros and Grant (p. 128) giving the number in a normal bill of fount in England, viz. 1·4:1.

General experimental conditions were the same as in Series 1–8. The subject sat comfortably, writing on an inclined surface. He worked for two minutes, rested for one, continued for two, rested for two. The next page was then taken, and so on, a session lasting about one hour.

Each page and type was worked eight times by each subject. The average score per page or face of these eight times became the final score of its legibility. The sums of the subjects' daily average totals of e's and t's together are shown in Table 13.

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TABLE 13

| *Position.* | *Type No.* | *Total score.* | *Percentage of Type 4.* |
|---|---|---|---|
| 1st | 4 | 1,413·250 | 100·0 |
| 2nd | 1 | 1,413·125 | 99·991 |
| 3rd | 7 | 1,391·000 | 98·4 |
| 4th | 5 | 1,383·625 | 97·9 |
| 5th | 3 | 1,377·000 | 97·4 |
| 6th | 6 | 1,366·125 | 96·7 |
| 7th | 8 | 1,357·625 | 96·1 |
| 8th | 2 | 1,354·000 | 95·9 |

The coefficient of correlation between subjects Nos.

19 and 20 was +0·48
19 „ 21 „ +0·23
19 „ 22 „ +0·58
20 „ 21 „ +0·14
20 „ 22 „ −0·14
21 „ 22 „ +0·07

Subject 21 again gives low correlations.

The sums of the subjects' daily average totals for different sheets in the same type are shown in

TABLE 14

| *Position.* | *Sheet No.* | *Total score.* | *Percentage of Sheet A.* |
|---|---|---|---|
| 1st | A | 1,505·625 | 100·0 |
| 2nd | B | 1,505·500 | 99·991 |
| 3rd | C | 1,480·750 | 99·7 |
| 4th | D | 1,478·000 | 98·2 |
| 5th | E | 1,468·000 | 97·5 |
| 6th | F | 1,455·375 | 96·7 |
| 7th | G | 1,454·000 | 96·6 |
| 8th | H | 1,449·500 | 96·3 |

The differences between the most and least legible types (Part 2), and between the most and least legible sheets (Part 3), the most legible expressed as percentages of the least legible, are shown in

TABLE 15

| *Subject No.* | *Part 2 (different types).* | *Part 3 (same type).* | *Difference per cent.* |
|---|---|---|---|
| | per cent. | per cent. | |
| 19 | 4·7 | 3·5 | +1·2 |
| 20 | 6·5 | 12·1 | −5·6 |
| 21 | 11·7 | 8·4 | +3·3 |
| 22 | 8·6 | 5·6 | +3·0 |
| Average . . | 4·1 | 3·7 | +0·4 |

The following facts are noteworthy:

(i) Type 1 is equal best in Series 9, and was best in Series 1–8, but it is equal with Type 4, which was equal worst in Series 1–8.

(ii) In Series 1–8 the difference between the most and least legible type was 70 per cent., in Series 9, 4 per cent. Judging from Table 15 it seems highly improbable that even this difference, much less the smaller ones between the other types, has any significance.

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(iii) The coefficients of correlation between the orders of legibility for Series 1–8 and 9 are:

| | |
|---|---|
| Subject 19 . . . . . | +0·19 |
| „ 20 . . . . . | −0·33 |
| „ 21 . . . . . | −0·07 |
| „ 22 . . . . . | +0·33 |
| Average . . . . . | −0·03 |

(iv) The only point of similarity between Series 1–8 and 9 is the superiority of Type 1, and this can be explained in the latter by its use alone for the first eight days as a practice type, and for the next eight as a daily practice as well as with the seven other types.

The total daily scores of all subjects in Series 9 increase fairly steadily day by day, and unmistakably from the first day to the last. If Type 1's superiority is due to subjects being familiarized with it before the other types, more of Type 1's increase in score should have occurred during its first eight (practice) days, than its second. But Type 1's second eight days were the first eight of the others; hence, while Type 1's increase in score slackened, the other types' were maintained; hence their scores should gain on Type 1's between its 9th and 16th day. Hence there should be a smaller difference between Type 1 and the least legible type on the last day of Part 2 than on the first. On the first, the difference was 21 per cent., on the last, 7 per cent.

The fact that Type 1 was also the most ordinary does not seem to have been responsible for its superiority, because Types 2 and 3, which were so similar, do not keep close to it in most cases. Their relative positions are shown in

TABLE 16

| Subject . . | 19. | 20. | 21. | 22. | *Average.* |
|---|---|---|---|---|---|
| Type 1 . . | 2nd | 6th | 3rd | 1st | Equal 1st |
| „ 2 . . | 8th | 8th | 6th | 6th | 8th |
| „ 3 . . | 4th | 1st | 7th | 7th | 5th |

(v) The coefficients of correlation between the final order of Series 9 and the orders according to the various dimensions of the faces given in Table 7 are all non-significant, except that of the a–z lengths, which is −0·73.

This series then gives no corroboration of the results of Series 1–8. It throws no light on the previous work, except in one point, to be mentioned later, nor on what are the factors on which legibility depends.

The only point of similarity between Series 1–8 and 9 is explicable without reference to legibility, and in Series 9 the differences between the types have no significance. The whole test, which is frequently used for testing 'intelligence', must be regarded as unsuitable for legibility.

### 4. SERIES 10

This was a rough attempt to corroborate in a different way Series 1–8, to discover a more realistic test than by using nonsense, and to utilize sense material by testing every type at every session, eliminating influences due to differences in the positions of the types by revolving their order.

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Reading was at maximum speed, aloud. The criterion and general experimental conditions were as in Series 1–8, Part 2, except that

(i) The order of the types was not 1, 2, 3, 4, 5, 6, 7, 8, but 4, 1, 8, 2, 6, 3, 7, 5. Contrasted and unusual faces thus alternated with standard faces.

(ii) Only ten exposures were given per type.

(iii) A session lasted about half an hour.

(iv) Subjects attended once daily, for eight consecutive days. Each type was thus tested once in every position. The average of its eight daily scores was its final score. These scores are shown in

TABLE 17

| *Type No.* | *Subject* 19. | *Subject* 20. | *Subject* 21. | *Subject* 22. | *Average. Actual.* | *Average. As percentage of No. 7.* |
|---|---|---|---|---|---|---|
| 1 | 802 | 928 | 816 | 1,137 | 921 | 98·2 |
| 2 | 814 | 943 | 824 | 1,129 | 928 | 98·9 |
| 3 | 806 | 940 | 827 | 1,150 | 931 | 99·3 |
| 4 | 765 | 931 | 793 | 1,125 | 903 | 96·2 |
| 5 | 823 | 934 | 822 | 1,146 | 931 | 99·3 |
| 6 | 775 | 933 | 803 | 1,168 | 920 | 98·1 |
| 7 | 827 | 951 | 850 | 1,125 | 938 | 100·0 |
| 8 | 828 | 928 | 803 | 1,144 | 926 | 98·7 |

The relations of the types to one another are shown in

TABLE 18

| *Position.* | *Subject* 19. | *Subject* 20. | *Subject* 21. | *Subject* 22. | *Average.* | *Average as percentage of No. 7.* |
|---|---|---|---|---|---|---|
| 1st | 8 | 7 | 7 | 6 | 7 | 100·0 |
| 2nd | 7 | 2 | 3 | 3 | 3 | 99·3 |
| 3rd | 5 | 3 | 2 | 5 | 5 | 99·3 |
| 4th | 2 | 5 | 5 | 8 | 2 | 98·9 |
| 5th | 3 | 6 | 1 | 1 | 8 | 98·7 |
| 6th | 1 | 4 | 6 | 2 | 1 | 98·2 |
| 7th | 6 | 1 | 8 | 4 | 6 | 98·1 |
| 8th | 4 | 8 | 4 | 7 | 4 | 96·2 |

The coefficient of correlation between Subject No.

| | | | |
|---|---|---|---|
| 19 | and | 20 | was +0·26 |
| 19 | ,, | 21 | ,, +0·48 |
| 19 | ,, | 22 | ,, −0·13 |
| 20 | ,, | 21 | ,, +0·82 |
| 20 | ,, | 22 | ,, −0·15 |
| 21 | ,, | 22 | ,, +0·06 |

The coefficients of correlation between the order of the types in Series 1–8 and 10 are :

| | |
|---|---|
| Subject 19 | +0·05 |
| ,, 20 | −0·54 |
| ,, 21 | −0·38 |
| ,, 22 | +0·60 |
| Average | −0·01 |

These figures show that there is

(i) Less difference between the best and worst type than in Part 2 of Series 1–8 (10 per cent.), or in Series 9 (4·1 per cent.), namely 3·8 per cent.

(ii) Very little agreement between the subjects.

(iii) Very little agreement with Part 1, Series 1–8.

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(iv) On the other hand, Type 4 is consistently bad, which agrees with Part 1, Series 1–8, but the relations of the comparable types differ widely from the same in Part 1 of Series 1–8. This is shown in

TABLE 19

| *Relative positions of the* | *Subject No.* 19. | *Subject No.* 20. | *Subject No.* 21. | *Subject No.* 22. | *Average.* |
|---|---|---|---|---|---|
| thick face and thin face | 7th | 5th | 6th | 1st | 7th |
| | 2nd | 1st | 1st | Equal 7th | 1st |
| narrow face and broad face | 8th | 6th | 8th | Equal 7th | 8th |
| | 3rd | 4th | 4th | 3rd | Equal 2nd |
| three standard styles | 4th | 2nd | 2nd | 2nd | Equal 2nd |
| | 5th | 3rd | 3rd | 5th | 4th |
| | 6th | Equal 7th | 5th | 6th | 6th |

Table 12 indicates that it is as hard to read very thick type as very thin, narrow as broad, but Table 19 that one in each case is much easier than another. And in the Series where this is so, the medium type is not the best.

(v) In Series 1–8 the three standard styles which look so much alike did not come close together, but in Series 10 on the whole they do.

More consistent results might have been obtained with more exposures per type. Undoubtedly there were too few. Nevertheless, in view of what is known about influences affecting speed, and of the inconsistencies, both internal and with the other series, the results of Series 10 should also be rejected.

### 5. QUESTIONNAIRES

Sixty individuals were canvassed for their opinions as to the relative merits of the eight types. They were expressly asked to ignore the aesthetic aspect. They were given one sheet of sense material in each type. They gave what information they could about their visual acuity. According to their own statements, the sixty individuals included

| | |
|---|---|
| 30 emmetropes | 4 hypermetropic astigmats |
| 6 myopes | 3 myopic astigmats |
| 6 hypermetropes | 1 myope-hypermetrope |
| 5 astigmats | 1 presbyope |

4 defects unknown.

The relative popularity of each type is shown in

TABLE 20

| *Type No.* | *Was placed* 1st times | 2nd times | 3rd times | 4th times | 5th times | 6th times | 7th times | 8th times | *Mean position.* | *Final order.* Type No. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 28 | 14 | 9 | 1 | 5 | — | 1 | 2 | 2·25 | 1 |
| 2 | 7 | 12 | 14 | 12 | 7 | 6 | 1 | 1 | 3·45 | 2 |
| 3 | 11 | 8 | 11 | 12 | 9 | 4 | 4 | 1 | 3·55 | 3 |
| 4 | 2 | 3 | 2 | — | 5 | 5 | 8 | 35 | 6·75 | 5 |
| 5 | 3 | 14 | 9 | 14 | 8 | 6 | 3 | 1 | 3·68 | 8 |
| 6 | 3 | 3 | 6 | 4 | 13 | 10 | 13 | 8 | 5·38 | 6 |
| 7 | — | 1 | 4 | 5 | 18 | 18 | 22 | 2 | 6·03 | 7 |
| 8 | 5 | 5 | 8 | 10 | 7 | 11 | 7 | 7 | 4·75 | 4 |

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The coefficient of correlation between this final order and that of

| | | |
|---|---|---|
| Series 1–8, | Part 1, | is +0·46 |
| „ | „ Part 2, | „ −0·31 |
| „ | 9 | „ −0·24 |
| „ | 10 | „ +0·19 |

The final order by preferences is compared with the experimental results of the four subjects for Series 1–8, Part 1, in the graph (p. 53). The following points may be observed:

(i) Type 1 is unmistakably the most popular, and Type 4 the least. This agrees with Series 1–8, Part 1.

The positions of the other types, especially Types 6, 7, and 8, are less clear.

(ii) The correlation with Series 1–8, Part 1, though low, is higher than with Part 2, or Series 9 or 10, which accords with the view already reached that the results of the three latter were non-significant.

(iii) Of the sixty individuals, thirty-two were canvassed by the writer in 1924, and twenty-eight by an assistant eight months later. The coefficient of correlation between the final orders of each group is **+0·98**.

(iv) In the first group were Subjects 19, 20, 21, and 22, who were canvassed after Series 1–8. The coefficients of correlation (R) for each subject between his order of preference and his experimental results are shown in

TABLE 21

| Subject No. | 19 R= | 20 R= | 21 R= | 22 R= |
|---|---|---|---|---|
| Series 1–8, Part 1 | +0·30 | −0·12 | −0·31 | −0·07 |
| „ „ Part 2 | **+0·60** | **−0·70** | +0·14 | −0·38 |
| „ 9 | −0·10 | −0·17 | −0·48 | −0·33 |
| „ 10 | **+0·54** | −0·13 | −0·24 | −0·26 |

Individuals gave various reasons for their choices. The qualities which are widely disliked are ' heaviness ', ' paleness ', ' crampedness ', uniform width of limb, and ' dazzle '. Only very few dislike serifs, or like condensation and uniform width of limb. Hence it is obvious that a general preference exists for a medium type, which would appear to be the reason why Type 1 is the most popular, and Types 2 and 3 were often grouped with or near it.

Many people noted that it was difficult to choose between the types at all except Nos. 1 and 4.

The correlation coefficient between the final order by canvassing and the order (descending) of the types arranged according to their

| | |
|---|---|
| a–z length is | +0·47 |
| Gauge | **−0·63** |
| Thickness of main-stroke | −0·20 |
| Thickness of hair-line | −0·50 |
| Contrast | +0·26 |
| Length of serif | +0·38 |
| Width of eye-piece of c | 0 |
| Width of eye-piece of e | +0·11 |

The canvassing was too little controlled and on too small a scale for its results to be accepted otherwise than with caution; nevertheless the figures indicate positive results in some directions.

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## V. CONCLUSIONS

On p. 24 it was said to be pretty generally agreed that the ideal type 'should be simple, fairly broad, with fairly thick limbs, but not too much contrast in thickness and thinness, and with fairly wide spacing'. Type 1, the best according to the experiments in Part 1 of Series 1–8, was simple, though the sanserif was simpler. In breadth and spacing Type 1 was, at a shade under 13 ems in a–z length and with a $9\frac{3}{4}$ set, equal 3rd, i. e. medium among the eight types. But it was not very thick, being 6th in width of mainstroke, and 8th in hair-line (27·7 and 8·1 hundredths of a mm.), and it had second largest coefficient of contrast, viz. 3·4, which is rather high.

The results then of these experiments accord to some extent with previous research. These—Part 1 of Series 1–8—are the only series whose results are relied on. The experimenter believes that *in the laboratory*, Type 1 was probably the most legible and Type 4 the least. He is far more doubtful (*a*) of the *sizes* of the differences and (*b*) whether the relative legibility of the types in the experiments holds in the ordinary world.

The hypothesis is here put forward that extremely large typographical differences must be present before it is possible to say that there is any difference in the objective legibility of types. Of types more slightly differentiated it is impossible to say that one is objectively more legible than another. Such types will be 'legible' according as they suit the psychological make-up of the reader. Hence the most legible type, in this subjective sense, is unlikely to be the same for all readers.

These two ideas—that within limits there is no objective optimum, and that only extremely violent changes in the stimulus can produce any significant variation in the reaction—are found in other psychophysiological fields. For example, it is no longer believed that there is one objectively best way of performing a manual operation in a given industrial process, but that the set of movements which prove best for one operative will not be the best for another.[1] Again, the effect on mental activity and general behaviour of reduced oxygen pressure does not vary all along the scale in direct proportion to the reduction of oxygen; the effect is negligible until the lack of oxygen is excessive, when the result is violent.[2]

There is then nothing intrinsically unlikely about this theory. It would explain why little agreement was obtained among the experimental results of subjects, and such indecision felt by the people canvassed in respect of the relative legibility of all but the best and worst types.

Other influences make for this result. Three types were ordinary in appearance, the rest unusual, and results indicate that to some extent it was its ordinariness which helped to make Type 1 the best, a view psychologically not improbable. If it is correct, to isolate and test a type's objective legibility must be almost impossible.

Another factor which clogs the influence of objective legibility

[1] See Myers, C. S. [2] Lowson, J. P., Bagby, E.

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is the ease with which reading habits are established. It is partly because this is operating without cease (no matter, within limits, of what description be the type) that the typographical differences must be large in order to evoke a change in the reaction. And if the results were inconclusive with types embodying their respective qualities—thickness, &c.—in unusually high degree, the differences in legibility with less extreme variants might be even less conclusively marked. For, though in Part 1 of Series 1–8 the difference between the best and worst types was 70 per cent., experimental conditions favoured wider differences than would exist in everyday life. Besides, this test did not embrace the entire problem.

It is affirmed that the importance of the questions of definition and criterion were stressed with good reason.

The matter of controls is also difficult. Practical obstacles prevent controls being applied in many respects as rigidly as is desirable. But in others absolute physical uniformity is a false condition which sacrifices the psychological uniformity that is much more important. Conditions are more truly normal and comparable if, for example, every subject reads, seated ordinarily, at the distance which suits him best, than if all read at the same distance with their faces artificially clamped to ensure it. Questions of control are to be settled not by a hard and fast rule applied rigidly to all, but individually by judgement.

The problem of legibility seemed simple at the outset ; it is in fact complex and elusive, and many questions have been raised which have not been answered.

Things being what they are, this is all to the good. For the practical, typographical problems of legibility are still far—further than many have believed—from scientific solution. Such solution is not possible until the manifold problems of principle, method, and technique have been acknowledged to exist and themselves solved. For this purpose are needed fewer opinions and more facts.

## VI. ACKNOWLEDGEMENTS

This investigation was carried out under the general direction of the Medical Research Council ' Legibility of Type Committee ', and for enjoying the benefit of their experience and advice and their respective branches of technical knowledge, which they have repeatedly put at my disposal, I am greatly indebted to all its members.

Besides this, however, I have to express my thanks to the chairman, Sir John Herbert Parsons, and to Mr. D. R. Wilson for procuring me access to references otherwise impossible to obtain ; to the secretary, Dr. E. Schuster, for constructing the apparatus, and for making translated abstracts of much of the foreign literature ; and to Mr. F. C. Bartlett, Director of the Psychological Laboratory, Cambridge, where the experiments were conducted. Besides acting for a considerable period as subject, he has given me invaluable assistance by frequent discussions and suggestions, by continual interest, and by his encouragement. To Miss S. C. M. Sowton is due the origin of the questionnaires.

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R. L. PYKE.

CAMBRIDGE, 1926.

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## APPENDIX I A

### EXPLANATORY NOTE TO 'HISTORICAL SUBJECT-*RÉSUMÉS*'

(i) The fullest and most exact judgement made by every author on any topic is the one entered in these *résumés*: if no quantitative statement is quoted, it is because none is made in the original; if no criterion, or details of an experimental basis are given, it is again because the author gives none. Further, the remarks of a writer, which are collected here under a single heading, may have been scattered in different parts of his own work, since his classifications were not necessarily mine; nevertheless, it is not believed that the distortion of a writer's views, or of the logical implications to which he would be bound, has anywhere been committed, and wherever possible their words are reproduced *verbatim*. If I have been guilty of misrepresentation, it has been unwittingly, and I apologize.

(ii) Where it appeared that an author had omitted to give his criterion, or an account of his experimental procedure, the spaces in the columns allotted for these are left blank. Where I have been unable to obtain the original paper or book and do not know whether an author has given his criterion or basis, or what those are, a note of interrogation appears.

(iii) Certain judgements hold, and were intended, only in a specialized sense; they belong to investigations into special sorts of 'legibility', and include those into telephone directories, railway time-tables, library catalogues, mathematical tables, and children's school-books. All these are marked with an asterisk (*), but others, drawn from the same settings, but capable of general application, are not.

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(iv) Judgements are of two sorts, general and particular. The general are recommendations for printing (negative and positive, some based on experiments, some not), in respect of the factor being discussed, as for instance, that ' the gauge of a face should never be less than 1·5 mm. or more than 2 mm.', or that ' all leading is bad '. The particular judgements state results only of an author's particular experiments, for instance, that, given his experimental basis and criterion, a certain face with gauge 1·6 mm. proved 75 per cent. more legible than another of 0·8 mm. This distinction is important.

## APPENDIX 1 B

### Historical Subject-*Résumés*

1. Contrast in thickness and thinness of limbs.
2. Criterion of legibility.
3. Definition of legibility.
4. Faces of type.
5. Illumination.
6. Indentation.
7. Leading.
8. Legibility of letters.
9. Length of line.
10. Margin.
11. Paper and ink.
12. Projectors, or long sorts.
13. Punctuation.
14. Serifs.
15. Size of type.
16. Spacing.
17. ' The Ideal Type '.
18. Thickness of limbs.

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## 1. *Contrast in Thickness and Thinness of Limbs*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Hansard, T. (1825). | None : *a priori*. | | Is opposed to extreme contrast. |
| Cattell, J. M'K. (1885). | Tachistoscopic reading with his fall-chronometer. Duration of exposure : $1\sigma$–$4\sigma$. [Slit too narrow for projectors to be wholly visible instantaneously.] | Speed of reading isolated letters ; proportion of correct answers to total numbers of exposures. | Doubts utility of using thick lines *and* thin lines. |
| Griffing and Franz (1896). | *Roman* lower-case (2 kinds : uniformly thick, and thin).<br>*German* 'block capitals' (2 kinds : one thick, the other thin).<br>Cattell screen, &c., 3 subjects.<br>Petrol lamp, 0·02 candle power. 1–4 words exposed at a time. Length of exposure $\frac{1}{2}$ second. | Fatigue through illumination threshold. | 'Thin hair-lines if with thick lines do not seem to diminish legibility.' |
| Morris, W. (1898). | None : empirical. | Aesthetic. | Entirely opposed to any degree. |
| Javal, E. (1905). | | | Is in favour of some contrast, for if limbs uniformly thick, optimum thickness depends on illumination. In practice, since we must allow for bad illuminations, limbs need to be thicker than the optimum. But, though there is no limit to badness of illumination, there is to thickness of limbs, for with limbs of more than a given uniform thickness a letter of given size would lose its shape. This danger-point is, however, reached less soon if we thicken some limbs, or parts of lines, only. Hence contrast. |
| Brit. Ass. Ctee. on influence of school-books on eyesight (1912). | Statistical inquiry. | Strain on (child's) growing eye. | * 'Excessive' contrast bad. 'Slight' thickening of limbs does not matter. |

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| | | | |
|---|---|---|---|
| Parsons, J. H. (1922). | *A priori.* | | Up to a point increasing contrast diminishes visibility but increases legibility; for, though a thin line may be harder to see as such, as a part of a design it may increase individuality and therefore increase legibility. |
| Ctee. on type faces and Govt. printing (1922). | None. ' The judgement of the trained human eye.' | | ' Undue thickness and thinness of strokes (and serifs) is undesirable.' |
| Morison, S. (1924). | | Aesthetic, and, in general terms, ' legibility '. | Opposed to ' excessive ' contrast. |

## 2. *Criterion of Legibility*

| *Author and year.* | *Criterion.* |
|---|---|
| Babbage, C. (1827). | * Majority of ' votes ' as to ' facility in reading ' with different shades of paper. |
| Javal, E. (1878–81 and 1905). | (i) Size of letters.<br>(ii) Fatigue on accommodation muscles.<br>(iii) Distance from normal eye at which pages of print can be read.<br>(iv) Distance from myopic eye at which pages of print can be just recognized.<br>(v) ' Confusability.'<br>(vi) Simplicity of letter form.<br>(vii) Degree of illumination necessary for a given reading performance. |
| Weber, A. (1881). | (i) Speed of reading (i. e. number of letters read per minute).<br>(ii) Degree of strain on child's growing eye. |
| Cohn, H. (1883). | The degree of myopia produced by reading. |
| Cattell, J. M'K. (1885). | Time taken to recognize 50 per cent. of words or letters when exposed for small fractions of a second. |
| Sanford, E. C. (1888). | (i) Distance at which (isolated) letters can be read (aloud).<br>(ii) ' The number of times a(n isolated) letter was read right or wrong, when seen for a very small fraction of a second ($2\sigma$ and $6\sigma$).' |
| Lamare (1892). | Number of letters that can be grasped by the eye in one reading pause. |

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2. *Criterion of Legibility (continued)*

| *Author and year.* | *Criterion.* |
|---|---|
| Griffing, H., and Franz, S. I. (1896). | (i) Time taken to read a given amount in different types (silently).<br>(ii) Number of words read (at maximum speed).<br>(iii) Percentage of words read to total exposed (in a fall-screen).<br>(iv) Intensity of illumination required for a given reading performance. |
| De Vinne, T. L. (1900). | Distance of book from eye at which type remains ' distinct '. |
| Finzi, J. (1901). | Errors. |
| Pergens, E. (1904). | Distance from the eye at which isolated letters could be read. |
| Dearborn, W. F. (1906). | (i) Speed of reading.<br>(ii) Number of eye pauses.<br>(iii) Number of refixations.<br>(iv) Degree of regularity of eye movements. |
| Hamilton, F. M. (1906). | Number of correct recognitions of letters in short exposures (21 $\sigma$) taking account of the different positions they occupied in a word. |
| Ruediger, W. C. (1907). | (i) Amount that can be grasped in a single fixation.<br>(ii) Amount read (silently) at normal and at maximum speeds. |
| Scott, W. D. (1907). | * (i) Time taken to read pages of a railway time-table (in two types).<br>(ii) Errors in reading same. |
| Kirschmann, A. (1908). | Distance (along various meridians) peripherally from a fixation point at which isolated letters could be read. |
| Maire, A. (1908). | Distance from the eye at which a row of letters can be read. |
| Wiegand, C. F. (1908). | Distance at which an approaching word became recognizable. |
| Dockeray, F. C. (1910). | Distance peripherally from fixation point at which two isolated letters (one on each side) could be recognized. |
| Huey, E. B. (1910). | (i) Speed of reading.<br>(ii) Fatigue on accommodation muscles.<br>(iii) Number of words read per fixation.<br>(iv) Light-reflecting power of paper. |

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| | |
|---|---|
| Brit. Ass. Ctee. on influence of school-books on eyesight (1912). | * (i) Strain on growing eye.<br>(ii) Strain on accommodation muscles.<br>(iii) Speed and accuracy of changing line.<br>(iv) Effect on reading rhythm.<br>(v) Height and breadth of short letters. |
| Roethlein, P. (1912). | Distance from the eye that single letters could be correctly recognized. |
| Legros and Grant (1916). | (i) Legibility coefficient<br>(ii) Specific legibility } viz. :<br>For a given pair of letters (e. g. a and s, e and c, i and l, &c.), calculate the ratio of 'the sum of the areas peculiar to the individual characters to the sum of the total areas of the two characters. This may be called the *legibility coefficient*. If 100 per cent. be taken as perfect legibility (i. e. no coincidence), then the difference between 100 per cent. and the legibility coefficient may be termed the *illegibility coefficient*. To obtain an accurate idea of the influence of each character on the illegibility as a whole, the illegibility coefficient is multiplied by the recurrence of the character as given in the fount bill and the product termed the *illegibility factor*. The sum of these illegibility factors divided by the total recurrence of the characters under consideration gives the *mean illegibility coefficient*. By this method the influence of different styles of face can be compared, provided other conditions (dimensions in gauge, main-stroke, hair-line, and set-width) are sensibly constant. How far these conditions result in uniformity can be measured by the ratio of the total area of the face of the character to the cross-section of the type. This figure given as a percentage has been termed *blackness*. It is obvious with increasing blackness, other conditions remaining constant, the coincident areas will increase and the legibility coefficients decrease, and vice versa. If there is no coincidence to consider, the actual legibility may be assumed to vary directly as the blackness ; hence the best comparative figure will be obtained as the product of the mean legibility coefficient by the mean blackness ; this the authors have styled the *specific legibility*.' |
| Weiss, A. P. (1917). | Degree to which letters can be thrown out of focus (maintaining a constant size) and still be recognized. |
| Baird, J. W. (1917). | * Time taken to find names in a telephone directory. |
| Bentley, M. (1921). | Time taken to read a given amount (aloud). |
| Govt. Ctee. on Type Faces (1922). | Judgement of 'the trained human eye'.<br>(*a*) For letters—aesthetic.<br>(*b*) For figures—'confusability'. |
| Burtt, H., and Basch, C. (1923). | Degree to which individual letters could be thrown out of focus (maintaining a constant size) and still be recognized. |
| Lyon, O. C. (1924). | * (i) Time taken to find names in a telephone directory.<br>(ii) Judgements of 300 subjects as to legibility of pages in same. |

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## 2. *Criterion of Legibility (continued)*

| *Author and year.* | *Criterion.* |
|---|---|
| Morison, S. (1924). | Aesthetic ; judgement as to ' compactness of appearance ' of whole page. |
| Sub-Ctee. of Permanent Consultative Ctee. on Official Statistics (1924). | * Fatigue, i. e. ' eye strain '. (For mathematical tables used for long periods at a stretch.) |
| Pratt, C. C. (1924). | * Time taken to find figures (i. e. dates) and letters. |

## 3. *Definition of Legibility*

| *Author and year.* | *Judgement.* |
|---|---|
| Javal, E. (1878–81 and 1905). | Of both a type-face and individual letters : ability to be read far off ; ability to be read in a dim light. |
| Weber, A. (1881). | Of a type-face : ability to be read quickly and easily. |
| Cohn, H. (1883). | Of letters : ability to be read easily, ' that is, fluently, for a good length of time and comfortably at a distance of 20 in. or 1/2 m. '. |
| Pergens, E. (1904). | Of individual letters : ability to be read far off. |
| Maire, A. (1908). | (i) He distinguishes legibility from visibility. The latter refers to the ' mark made upon the paper by a letter, and is measured by the distance from the eye at which the letter whole, if alone, ceases to be distinguishable from the paper, or, if among other letters, becomes merged with them. It varies directly with the intensity of illumination.'<br>(ii) ' Legibility, on the contrary, consists in it being possible to define clearly with the eye the design of the letter, that is, its contours, and therefore the *ensemble* of the letters of a single word. A given character is legible only at a certain distance, which is shown by (the reader's) visual acuity. Legibility . . . stands in direct relation to (1) letter-shape, (2) ratio of letter-height to letter-width, (3) thickness of main-strokes and hair-lines, and (4) the internal and surrounding white spaces.' |
| Kirschmann, A. (1908). | Of individual letters : ability to be recognized peripherally. |
| Bentley, M. (1921). | Of a type-face : ability to be read quickly and easily. |

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## 4. *Faces of Type*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Hansard, T. C. (1825). | | | Opposed to (i) extreme kinds of face design.<br>(ii) Excessively fine hair-lines.<br>(iii) Excessively fine serifs.<br>(iv) Extreme thick-and-thinness.<br>(v) Uniform thickness (' Egyptian Antique ').<br>(vi) Stresses importance of good paper. |
| Javal, E. (1878 and 1905). | Apparently a very rough experimental basis without adequate controls or consistency. In any case no details are given in his book or in any of his articles. | Maximum distance from eye that letters or words can be read. | *Upper-Case.*<br>(i) ' Norman ' the most legible (very thick-and-thin, and squat).<br>(ii) Serifs a corollary from thick-and-thinning owing to irradiation.<br>(iii) Garamond and Jaugeon best of modern faces in use between 1740 and 1840.<br>(iv) Fifteenth-century style is the best.<br>(v) Condensed to be avoided ; but diminished gauge is a lesser evil. |
| Fick, A. (188(5 ?)). | | | Favours square-shaped letters. |
| Sanford, E. C. (1888). | Movable carriage holding box set (*a*) within easy reading distance and moved by given amounts, farther away, (*b*) too far away and moved by subjects to limen. Isolated lower-case letters. Snellen optotypes size D=1·25, i. e. non-projectors =1·8 mm. high.<br>Day lighting and artificial (by flashes in dark box in dark room).<br>5 subjects, ' 2 quite far sighted, 1 moderately, 1 normal, and 1 near sighted but wearing spectacles '. | Distance at which isolated letters could be read right (in proportion to total number of exposures). | Letters should possess ' simplicity of outline, concentration of the differentiations upon one particular '.<br>Breadth is generally a greater advantage than height.<br>' Broad short letters are better than long narrow ones.' |
| Lamare (1892). | (i) Counting number of eye movements by finger on (own) lid.<br>(ii) Eye-attachment making taps on a drum. | Amount that can be embraced by the eye in a pause. | *Lower-Case.*<br>Favours condensed faces of good-sized gauge. |

## 4. *Faces of Type* (*continued*)

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Griffing, H., and Franz, S. I. (1896). | A hooded petroleum lamp (fairly constant) through a ground glass (area 5 × 5 mm.) giving about 0·02 candle-power.<br>20–30 minutes for eye adaptation.<br>3 subjects.<br>Letters exposed through Cattell fall screen. Length of exposures: 1/20 sec.<br>Letters in a row, 1–4 words. | Fatigue through illumination threshold. | Upper- and lower-case, in descending order of legibility:<br>(i) Block 'thick' (limbs 0·5 mm.) (upper-case).<br>(ii) Roman 'II' 'thick and thin' (limbs 0·5 to 0·05 mm.) (lower-case).<br>(iii) Roman 'III' 'uniformly thick' (about 0·2 mm.) (lower-case).<br>(iv) Block 'thin' (0·15 mm.) (upper-case).<br>(v) German Gothic. |
| Morris, W. (1898). | | | 'The ugly and vulgar illegibility of the modern face, and the elegance and legibility of the old style' are particularly striking in the numerals. |
| De Vinne, T. L. (1900). | For (i) 'Select equally well printed pages of Old Style and Modern Face of uniform body and thickness of stem, and place them in a favourable light. Then move away from them and note which becomes indistinct sooner than the other.' | Distance of book from eye at which type remains 'distinct'. | (i) Old Style is 'superior in distinctness' to Modern Face. Modern Face 'is not a good type for reading; it needs readers of excellent sight'.<br>(ii) 'Firmness of line is the best feature of Modernized Old Style.'<br>(iii) 'Sharp lines and dazzling serifs make all the light faces hard to read.'<br>(iv) 'For all bodies below 10-point a narrowing that makes their lower-case alphabets thinner than that of the prevailing standards is not to be recommended.' |
| Burgerstein, L., and Netolitzky, A. (1902). | Investigation in schools. | | They prefer Antiqua to Fraktur, particularly for upper-case. |
| Cohn, H., and Rübencamp, R. (1903). | | (i) Ability to be read at a distance of 20 in.<br>(ii) Influence upon myopia. | Prefer Antiqua to Fraktur. |

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| | | | |
|---|---|---|---|
| Messmer, O. (1904). | Ordinary reading without tachistoscope. Few subjects. Reading forwards, and reading backwards. Time taken for reading 100 and 500 words and 100 and 500 letters. | Speed not alleged to be criterion for general legibility, but what else his own criterion is, he does not say. | Roman is on the whole read more quickly than German Gothic (Fraktur). |
| Ruediger, W. C. (1907). | Tachistoscopic exposure for 5 $\sigma$ of a lowercase n or u in 10-point with eye kept constant 30 cm. distant. The n or u tried at 10, 15, 20, 25, 30, 40 mm. laterally from the fixation point. Subjects employed only in normal health. | Amount that can be grasped in a single fixation. | Is opposed (by implication) to condensed types. The extent of the horizontal field of distinct vision varied *very little* for the fastest and slowest readers. He infers that not even the rapidest reader makes use of the full extent of his visual field available for seeing words. Therefore no time is lost in reading ' owing to the arrangement of words on the page '. Therefore with print of ordinary size we ' can take in the material faster than the mind can assimilate it, and there is no call for methods of arranging words so that more can be crowded simultaneously into the field of distinct vision '. |
| Scott, W. D. (1907). | 2 pages of a railway time-table, each set up in light-faced small type and heavy-faced large type on same body.<br>6 subjects reading at maximum speed the whole page. (No control over visual acuity or illumination [daylight ? A very special sort of legibility.] Experiments too roughly carried out and reported to be trustworthy].) | (i) Time taken.<br>(ii) Errors. | *Time.* *Errors.*<br>* Large heavy-faced type . . . . 100 100<br>Small light-faced type . . . . 113·3 145<br>Large heavy-faced type the more legible. |
| Brit. Ass. Ctee. on influence of school-books on eyesight (1912). | None. Statistical inquiry. | Strain on (child's) growing eye. | * (i) Should not be heavy at cost of counters.<br>(ii) Should not be condensed.<br>(iii) Should be broad and square, rather than elongated.<br>(iv) Undecided between Old Style and Modern Face, as such, because there are good and bad among both.<br>Modern is ' called more legible, but Old is more flowing and continuous in words '. Minimum height more often ignored in Old. Minimum height the essential; so whichever style provides that is favoured. |

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## 4. *Faces of Type* (*continued*)

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Roethlein, P. (1912). | (i) Isolated letters (upper- and lower-case) with equal space (3·7 cm.) between a given letter and its neighbours on same line and adjacent lines on sheets 21 × 36 cm. of 'white coated book-paper 25 × 30–80'. Each sheet contained 28 letters all of the same face and case (i.e. the alphabet with 2 letters repeated) arranged in 4 equal rows, in a random order. The sheet was placed in a carriage which slid slightly upwards as it approached the observer, and was moved by intervals of 20 cm. towards the observer. There were 20 different sheets of upper-case and 26 of lower-case letters in 10-point.<br>6 subjects (familiar with psychology), emmetropes, or with 'adequately corrected vision'. Each subject gave 104 readings. He read each sheet twice, with an interval of 'several days'. The second time each sheet was cut across and down so that letters formerly at edges of sheet were now central. Subjects read from left to right downwards, and, on second readings, from right to left and upwards. They 'read at a uniform tempo, substituting " blank " for the name of any letter . . . not easily decipherable'. Subjects' heads were placed in a head-rest. The room was 'semi-darkened'; the illumination was evenly distributed from electric bulbs, round the test sheet, in a box 55 × 40 cm. and 25 cm. | Distance from the eyes at which isolated letters could be read correctly. | (i) In descending order of legibility.<br>*Roman Faces.*<br>*Upper-Case.*<br>Jenson.<br>Bullfinch.<br>Cheltenham Wide.<br>Century Old Style.<br>Clearface.<br>Cheltenham Old Style.<br>Della Robbia.<br>News Gothic.<br>Century Expanded.<br>Caslon Old Style.<br>De Vinne No. 2.<br>Ronaldson.<br>Cushing Monotone.<br>Cushing No. 2.<br>American Typewriter.<br>*Lower-Case.*<br>News Gothic.<br>Bullfinch.<br>Clearface.<br>Century Old Style.<br>Century Expanded.<br>Cheltenham Wide.<br>Jenson.<br>Della Robbia.<br>Cushing Old Style.<br>Ronaldson.<br>Cheltenham Old Style<br>De Vinne No. 2.<br>American Typewriter.<br>Caslon Old Style.<br>Cushing Monotone.<br>Cushing No. 2.<br>(ii) *Bold Faces.*<br>*Upper-Case.*<br>Century Old Style Bold.<br>Cheltenham Italic.<br>Clearface.<br>*Lower-Case.*<br>Century Old Style Bold.<br>Cheltenham Old Style Bold.<br>Clearface Bold.<br>(iii) *Italic Faces.*<br>Clearface Italic.<br>Clearface Bold.<br>Cheltenham Italic.<br>De Vinne Italic.<br>Clearface Italic.<br>Cheltenham Italic.<br>De Vinne Italic.<br>Clearface Bold. |

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deep. 'Adequate' accommodation time was given.

(ii) Groups of letters. Apparatus and method as in (i). Only lower-case letters, and only 8 faces: Bullfinch, Caslon O. S. No. 540, Century O. S., Century Expanded, Cheltenham Wide, Cushing O. S. No. 2, Cushing Monotone, News Gothic, Scotch Roman. Groups, printed in 3 lines, were arranged so as 'to introduce as many difficult and confusing combinations of letters as possible' (based on confusions in preliminary work, and on experience of expert proof-reader). An example is as follows:

Ksitugy cdzxpbj ftoceygqa wrvlindk hknurfkxzqg munimm bhwvjyst oceo wvxarfxzp ybhdonactilsf dnupqcetrlj.

3 subjects (3 of those acting in (i)). Each gave 2 readings of each face—an average of 24 readings of each letter of each face. Two sorts of paper: 'White coated book-paper 25 × 30–80' (same as in (i)), and a 'rough-finished, very slightly yellowish paper.'

(iv) *Extra Bold Faces.*

| | |
|---|---|
| Bold Antique. | Bold Antique. |
| Franklin Gothic. | Franklin Gothic. |

(v) 'The relatively heavy-faced types prove to be more legible than the light-faced types. The optimal heaviness of face seems to lie in a mean between the bold faces and such light faces as Scotch Roman and Cushing Monotone.'

Legros and Grant (1916).

'Specific legibility.' (For definition, see 2, Criterion of Legibility.)

In descending order of legibility:

(i) Latin { 1. Old Style. 2. Modern Face. 3. Sanserif.

'Blackfriars is very legible.'

(ii) Fraktur is 'extremely illegible.'

## 4. *Faces of Type* (*continued*)

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Legros and Grant (1916), and Legros (1922). | | (i) Legibility coefficient.<br>(ii) Specific legibility.<br>(For definition, see 2, Criterion of legibility.) | |

*Figures.*

| | *Mean legibility coefficient.* | *Blackness.* | *Specific legibility.* |
|---|---|---|---|
| Modern Face | 52·3 | 17·8 | 9·31 |
| Modernized Old Style | 46·8 | 14·9 | 6·97 |
| Old Style Blackfriars | 20·4 | 21·5 | 4·39 |
| Sanserif | 18·0 | 26·8 | 4·82 |

'Legibility can be increased by keeping the tail-dots near to the upper and lower lines respectively.'

'Sanserif figures afford examples of illegibility caused by the too close approach of the tails of the 6 and the 9 to the bowls, and by the narrowness of the opening of the counter of the 5, and, sometimes, by the closeness of the tails of the 3.'

Figures and points made to the set-width of two thick spaces and on the thick-space set respectively (i. e. on 2/3 and 1/3 the body respectively) are more legible than, what is usual, those cast on the en set and middle space set (i. e. 1/2 and 1/4 the body) respectively.

*Vulgar Fractions.*

Methods of printing in descending order of legibility.

(i) Inclined arrangement, the figures being of a somewhat smaller size than the body fount, and those for the numerator being set 2 or more points, according to the size, above the line of the denominator figures.

(ii) With the solidus or diagonal stroke with figures of more than half the body-size.

(iii) Figures of half the body-size, with the horizontal bar. The bar adds additional blackness. This method is bad.

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| | | | |
|---|---|---|---|
| Ctee. on Type Faces and Govt. Printing (1922). | None. 'Judgement of the trained human eye.' | Simplicity. Breadth. Degree of contrast. Interlinear space. Area of 'counters'. | *A. Letters.*<br>Old Face and Old Style better on the whole than Modern Face.<br>*B. Figures.*<br>(i) Modern or Modernized Old Face best; they are strong against breakage and lessen the confusability of 3, 5, 6, 8, 9.<br>(ii) The characteristics of the ideal type 'are fulfilled less in lino- and mono-types than in hand-set types'.<br>(iii) The first two contain different faces in an inadequate number of sizes.<br>(iv) For title-pages types should be used only of one fount and family. |
| Parsons, J. H. (1922). | | Legibility (as opposed to aesthetic criterion). | (i) For titles, &c., on Govt. reports, and blue-book covers, letters should not be of one family of presses only, but of several suitably chosen for contrast.<br>(ii) Condensed 'have something in their favour'. |
| Updike, D. B. (1922). | | | 'Modern face types appear, at first sight, clearer to the eye and more easily read than old style, but they are really less so in the long run.'<br>'Modern face type is admirable for books of a scientific or technical character.' |
| Burtt, H., and Basch, C. (1923). | Individual letters cut from printers' catalogues thrown on field 6 in. × 6 in. on ground glass lit by 'daylight' lamps in a dark room. Subject's forehead in rest 15 in. away. Seven student-subjects.<br>'Focal variator' for altering focus: readings in 100ths of 1/16 in. Upper- and lower-case. JKLQUXYZ not used. | Distance that individual letters could be thrown out of focus (maintaining constant size) and still be recognized. | In descending order of legibility:<br>1st. Cheltenham (medium).<br>2nd. Baskerville Roman.<br>3rd. Bodoni.<br>All 14-point.<br>The relative merits of these types not maintained strictly in all letters, but most emphasized when light strokes are involved. |

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## 4. *Faces of Type (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Sub-Ctee. of Permanent Ctee. on Official Statistics (1924). | Opinions and quoted opinions. | Fatigue. | Figures.<br>(i) The particular fount immaterial provided it is bold, round, and clear.<br>(ii) The counters of 3, 5, 6, 8, and 9 should be open.<br>(iii) 3 should be flat-topped.<br>(iv) Old Face, Old Style, Modernized Old Style, Modern, and certain Sanserifs give good results.<br>(v) Yet there is less risk of confusion of 3, 5, 6, 8, and 9 in many Old Faces.<br>(vi) Where there is no fatigue, Modern or Modernized Old Faces are preferable. |
| Lyon, O. C. (1924). | | | Faces should be ' opened-up ' as much as possible, i. e. counters should be large. |
| Kerr, J. (1925). | | | (i) He thinks that Latin type has more legible letters than Fraktur, but is unwilling to reject altogether the idea, popular with some German writers, that Fraktur makes more easily recognizable and characteristic word-wholes.<br>(ii) ' Sanserifs (letters) would seem (sic. = " might be thought " ?) the best, but owing to irradiation are not as legible as letters with thicker ends.' |

## 5. *Illumination*

| | | | |
|---|---|---|---|
| Javal, E. (1879–81 and 1905). | None. Apparently based on investigations among schools. | | (i) The visibility of letters (as distinct from their legibility and like, presumably, the visibility of any object) varies in direct proportion to the illumination.<br>(ii) *In schools* the lighting should be so strong that the darkest part of the room on the darkest day should be ' sufficiently light ' (by day).<br>(iii) Sky-lighting is best.<br>(iv) 1 gas flame per child is necessary by night. |

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| | | | |
|---|---|---|---|
| Cohn, H. (1883). | None. Statistical inquiry and *a priori*. | Fatigue and eye-strain in children. | * *For Schools.*<br>A. Daylight.<br>(i) Sky- (vertical) lighting best.<br>(ii) If windows, they should face east or south.<br>(iii) There should be 1 sq. ft. of glass to 5 sq. ft. of floor.<br>(iv) Windows should be 4 ft. wide × 10 ft. high and their bottom edge 1 metre above floor.<br>(v) They should be on reader's left and<br>(vi) Obliquely incident light should be avoided.<br><br>B. Artificial light.<br>(i) There should be 1 gas flame for 4 children.<br>(ii) Lights should be shaded. |
| Cattell, J. M'K. (1885). | Fall chronometer. Isolated letters seen through slit; grey spot fixated on black surface; screen dropped at will of observer.<br>[Slit was too narrow for a 'projector' to be wholly visible instantaneously.] | | He found that on the average about 0·25 $\sigma$ less was needed to name letters by daylight than by lamp-light. [Both the day- and lamp-light varied from one session to another; it seems doubtful therefore whether a difference of 1/4000th of a second can be relied on as significant.] |
| Griffing, H., and Franz, S. I. (1896). | (i) Reading of passages of 622 words in the Bible. Times taken by the observers, mostly students, ignorant of their results, however.<br>(ii) Cattell fall screen.<br>3 subjects.<br>Petrol hooded lamp of 0·02 candle-power. 1–4 words exposed at a time. Length of exposure 1/2 second. | Amount read. For (iii) General fatigue. | (i) Incandescent gas-light (white) best. Daylight next best. Petroleum lamp-light is worst.<br>(ii) No effect by varying daylight from 50 to 1,500 candle-metres.<br>(iii) Above the 3–10 candle-metre level only very small effects on reading result from changes in illumination, but below, very large effects. '100 c.-m. is a safe limit.'<br>(iv) They infer that, provided artificial light is strong, steady, and white enough, it is as good as daylight.<br>(v) White light is better than yellow.<br>(vi) Daily variations in sensitivity of a subject impede this inquiry. |

## 5. *Illumination (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Parsons, J. H. (1914). | | | 'Minimum illumination of the types which permits of normal visual acuity with Snellen's test is 2–3 metre-candles. Vision improves as illumination is increased to 10 m.-c., after which it remains almost constant up to 30 m.-c. and over.' |
| Berkowitz, J. H. (1920). | (i) Intensive survey of conditions in U.S.A.<br>(ii) Questionnaires over an extensive field in U.S.A. | | * *For Schools.*<br>(i) Area of windows should be 1/4 to 1/5 that of floor.<br>(ii) 'Windows should be placed on one side of the classroom so that the light will fall upon the writing surface of the desk from the left side of the pupil.'<br>(iii) There should be uniform light distribution, both natural and artificial.<br>(iv) There should be no glare. |
| Caldwell, F. C. (1920). | Inspection of schools in U.S.A., and review of previous work. | Strain on child's eye tending to cause myopia. | * *For Schools.*<br>(i) 'Light should come from the left side of the students, and there should be no windows in front.'<br>(ii) The area of windows should be 1/4 to 1/5 that of the floor. |
| Luckiesh, M., Taylor, A. H., and Sinden, B. H. (1921). | Reading matter (3 lines visible at a time) on drum revolving on horizontal axis behind screen with slit. Screen and background of reading matter had about same reflection factor. Subjects' eyes looked through slit 40 cm. from drum. Light source 'essentially a 75-watt gas-filled tungsten lamp behind diffusing glass screen, so arranged that intensity of illumination on test object could be controlled without change of colour of the light, and with no lack of uniformity'. Extraneous light kept out by black metal shields. | | Speed of reading increased with an increase of artificial illumination from 0·4 to 25 foot-candles. The rate of increase in speed, however, diminished throughout. With an illumination of 5 foot-candles, the speed of reading was 10 per cent. greater than with one of 4 foot-candles. Authors think the optimum intensity depends partly on the maximum available. |

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Speed of drum's revolutions measured by motor-car speedometer. Old English type reduced photographically to 8-point [from what size ?] set in 2 columns of 1¼ in. width each. Observers regulated speed of drum till they obtained a speed they liked best; then speed measured, and the operation repeated at other illuminations. These were 0·39 f.-c., 1·56 f.-c., 6·25 f.-c., and 25 f.-c. They were used first in ascending, then in descending order. 2 observations taken at each, and averaged.

Reading matter was :

*Trans. Ill. Eng. Soc.*
*Life of Edison.*
*Scientific American* (monthly).

| *Apparent diffuse reflecting factor.* |
|---|
| 80 per cent. |
| 89·5 ,, |
| 80·5 ,, |

Wood, F. H. (1921).

| *Point type.* | *Lines per in.* |
|---|---|
| 11- | 6 |
| 12- | 5·6 |
| 9- | 7·2 |

Illuminating Engineering Society (1924).

Inspection of schools.

* *Day lighting* (*in schools*).

(i) Windows should be grouped on the left of pupils as seated and directly opposite their desks, none reaching beyond the front desks.
(ii) Windows must extend to the ceiling, and
(iii) Must have a minimum area equal to 1/5 of the floor space.

* *For Schools.*

(i) The day lighting 'should be so arranged that pupils are compelled to face windows'.
(ii) For artificial lighting the light at the desk surface should be not less than 5, but at optimum 10 foot-candles.

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## 6. *Indentation*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Slefrig, S. (1905). | | | The lines should be indented on the right. There should be no hyphenation. |
| Dearborn, W. F. (1906). | Analysis of eye movements by means of photography of a pencil of light reflected from the cornea. Silent reading. | Regularity of eye movements. | Opposed to it, especially for children, as it upsets the motor innervation rhythm. |
| British Assoc. Ctee. on influence of school-books on eyesight (1912). | *A priori*; or perhaps a statistical inquiry; it is not clear which. | For (ii). Reading rhythm. | * For children especially :<br>(i) Approximate but not absolute uniformity of length of line is desirable.<br>(ii) Indentation helps unconscious swing which is necessary for good intelligent reading. |
| Baird, J. W. (1917). | 32 subjects (skilled to unskilled), (*a*) telephonists, (*b*) general clerks, (*c*) business men.<br>Artificial and day lighting; intensities of each varied. A name spoken or shown to subject, who had to find corresponding number and speak it aloud.<br>9,840 exposures, i. e. each subject had 30 exposures in 4 arrangements of print. Sessions short, avoiding fatigue. Practice effects eliminated. | Time taken to find names in a telephone directory. | * Average time taken to find a number in a page :<br>4 *cols. solid.* — 10·69 sec.<br>4 *cols. alternate lines indented.* — 10·14 sec.<br>4 *cols.* 1/2-*point' lead.* — 9·28 sec.<br>The indented form of page proves to be but little superior to the ordinary. . . . Indenting is much less efficacious than leading. . . . If we may assume that alternate indentation really facilitates the reader's endeavour to follow the horizontal line of print our data would seem to indicate that misreadings which are due to the crowded conditions of the printed page are of very much greater significance than misreadings due to one's tendency to wander away from the horizontal line of print.' |

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## 7. *Leading*

| | | | |
|---|---|---|---|
| Javal, E. (1880 and 1905). | None. Rough-and-ready impression by scanning pages set up leaded and solid. | Eye-to-book distance. | He objects absolutely—a 'luxury'—and prefers a bigger type; would even prefer increase of 1-point in tails of descenders to increase of 1-point of leading. But he also states that increasing legibility is a practical problem, as paper costs something and therefore leading and spacing often cannot be afforded. [He seems to imply here that, economics apart, there might be something in favour of leading.] |
| Weber, A. (1881). | Investigation in schools. | Strain on child's growing eye. | Does not decide any absolute amount, but stresses importance of the ratio of interlineage to gauge : 2 : 1·5 for Fraktur; 2 : 1·75 for Antiqua. |
| Cohn, H. (1883). | | Fatigue. | (i) Is in favour of it. 'A smaller type leaded is, or can be, more legible than a larger type solid.'<br>(ii) More important is the ratio of lead to gauge. 1·5 : 3 and 2·5 : 3 are good minimum ratios for gauge to interlineage.<br>(iii) Not more than two lines of print should occur in depth of 2 cm. on the page of any book or newspaper.<br>(iv) Parsons says Cohn favours a minimum of 2·5 mm. lead to 100 mm. length of line (= interlineage ?). |
| Fick, A. (188(5 ?)). | | Ease in changing from line to line. | (i) It should vary according to length of line.<br>(ii) The optimum proportion of length of line to interlineage is 40 : 1. |
| Griffing, H., and Franz, S. I. (1896). | 3 subjects (students).<br>Exposures of 1–4 words at a time in Cattell screen.<br>Petrol hooded lamp of 0·02 c.-p. | Fatigue by illumination threshold. | Pearl more legible when leaded than not, i.e. when interlineage was increased from 0·8 mm. to 1·3 mm. But only a slight improvement found. |
| Sack, N. (1896). | Investigation in schools. | | * The interlineage should not be less than 2·5 mm. |

## 7. *Leading (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Morris, W. (1898). | None ; empirical. | Aesthetic appearance, and legibility proper, undefined. | Is opposed absolutely to it. [Followed Venetian tradition of fifteenth century, especially Jenson, 1470.] |
| Dearborn, W. F. (1906). | 3 or 4 subjects. Photography (of corneal reflection of beam of light) of eye movements. Type-written matter of same spacing and printed, with different 'leads'. [His results on leading were a side issue incidental to work on length of line.] | Number of refixations. Number of eye-pauses. [Consistent with rest of his work.] | 'An increase of spacing between the lines increases legibility as much as a larger size of type.' |
| Williamson, R. T. (1906). | | Eye-strain produced by protracted reading. | 'A small type with the lines well separated is more easily read than a larger type with the lines close together.' |
| Maire, A. (1908). | | Intellectual fatigue. | For works on mathematics, chemistry, physics, medicine, and natural sciences a 9-point body with $1\frac{1}{2}$- to $2\frac{1}{2}$-point lead is better than solid. |
| Huey, E. B. (1910). | | | 'Leading is doubtless a mistake when the size of type is less than 1·5 mm. for lower-case non-projectors' (i. e. if gauge less than 1·5 mm. it should be increased to this minimum before leading is used). |
| American School Hygiene Association (1911). | | | *For adults.* The minimum leading (= interlineage ?) should be 2·5 mm. |
| Brit. Assoc. Ctee. on influence of school-books on eyesight (1912). | None—*a priori* and statistical inquiry. | Strain on (child's) growing eye. | * Interlineage should vary with size of type ; too little space fatigues, too much involves waste and 'has no advantage as regards legibility'. |

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| | | | |
|---|---|---|---|
| Baird, J. W. (1917). | 32 subjects (skilled to unskilled. Different V. A.'s). Artificial and day lighting of different intensities. A name spoken or shown to the subject, who had to find the number and speak it aloud.<br>9,840 exposures, i. e. each subject had 30 exposures in 4 arrangements of print. Sessions short, avoiding fatigue. | Time taken to find names and numbers in a telephone directory. | * (i) 'Within certain limits degree of legibility varies directly with the width of the blank space which appears between adjacent lines of a printed page (i. e. with thickness of leading).'<br>(ii) Average time taken to find a number in a page (of directory) of<br>3 *cols. set solid.* 10·36 sec.<br>4 *cols. set solid.* 10·69 sec.<br>4 *cols.* 1/2-*point lead.* 9·20 sec.<br>'It is obvious that the 4-column leaded page is much more (13 per cent.) legible than either of the others.' |
| Bentley, M. (1921).<br>F 2 | 10 lines of Monotype News Gothic (a Sanserif) on 'fine heavy white paper' on sheets 6 in. × 7½ in. Length of line: 3 15/16 in. 3 sizes of type: 12-point and photographic reductions equivalent to 9-point and 6-point. Variety of topics.<br>18 subjects giving a total of 6,640 readings. Subjects chose their own optimal distance for reading, which was increased. They read at that maximum speed and had to 'say "blank" and continue, if a strange or unclear word appeared'. Fatigue avoided by short spells and frequent rests. Subjects looked down a dark tunnel in a dark room, and concealed electric bulbs gave a reflected light on the sheet of paper. Subjects fixated a white spot on a grey field. A daylight series totally confirmed all the results by artificial light. | Time taken to read a given amount. | (i) 'Leading helps up to about 1/10 in., that is, a 7-point lead. This is much better than solid.'<br>(ii) The 7-point lead was best, with practically no exception, for all [1] distances, subjects, and type-sizes. I. e. in the photographic equivalents of 9- and 6-point, what corresponded, among the 7 leads used, to a 7-point lead with the 12-point type, also proved the best. Hence 'it seems that the critical or optimal leading is not entirely a matter of the interlinear spacing or of the clear space left above and below the line, and not entirely a matter of the drop of the eye in passing from the end of one line to the beginning of the next. It appears rather to depend upon the *ratio* of letter-height to interlinear space.'<br>(iii) 9-point lead and solid about the same.<br>(iv) He found a maximum average saving *at the rate* of 4 minutes per hour.<br>[1] = 'all used'. |

## 7. *Leading (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Legros, L. A. (1922). | | | 'It occasionally happens that a descending character in one line comes immediately over an ascending character in the next line, and the risk of the narrow space between them being filled with ink demands that a minimum of white shall be left between these black lines; usually this should not be less than three-thousandths of an inch.' |
| Parsons, J. H. (1922). | | | 'It is quite certain that the advantage of leading, if any, is, if not quite, almost negligible.'<br>[He may mean (i) that it actually makes no difference to legibility what the interlineage is, or (ii) that it does, but that this can be better or as well obtained by other means.] |
| Lyon, O. C. (1924). | 6-point type solid and 6-point on 7-point body. Pages of a telephone directory set up in both.<br>3 classes of subject:<br>(*a*) Telephonists.<br>(*b*) General clerks.<br>(*c*) Business men.<br>(*a*) looked up names read out to them.<br>(*b*) read page at limit of vision.<br>(*c*) looked up 10 names in each arrangement.<br>'Most subjects appeared to have normal sight. Some wore glasses.' [No tests.]<br>'Normal daylight.' | (i) Time taken to find names in a telephone directory.<br>(ii) Judgements of 300 subjects as to legibility of pages in above. | * (i) No measurable difference between 6-point solid and 6-point with 1-point lead.<br>(ii) 1-point lead had greater aesthetic appeal and was generally preferred.<br>[Not a general assertion on legibility but only regarding telephone directories.] |
| Sub-Ctee. of Permanent Consultative Ctee. on Official Statistics (1924). | | Fatigue. | *Figures.*<br>In tables there should be (i) 'an adequate' spacing between each line, and (ii) a wider space after every 5 lines. |
| Kerr, J. (1925). | | Number of lines visible in area of distinct vision. | 'Legibility appears to increase with leading; probably it is decreased as soon as one line above or below comes within the small fixation area of distinct vision.' |

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## 8. *Legibility of Letters*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Cattell, J. M'K. (1885). | Gravity chronometer exposures from $1\sigma$ to $4\sigma$. Grey fixation-point on black ground.<br>Day- and lamp-light used.<br>Isolated letters. [Slit too narrow for the whole of a projector to be visible simultaneously.] | Time taken to recognize 50 per cent. of letters exposed. | *Upper-case.*<br>In descending order of 'legibility':<br>WZMDHKNXAYOGLQISCTRPBVFUJE<br>Correlation coefficient with:<br>(i) Finzi . . . . . −0·05<br>(ii) Kirschmann . . . −0·19<br>(iii) Roethlein . . . . +0·12<br>(iv) Hartridge and Owen . . +0·08 (H. and O. omit WIQM and G)<br>(v) Banister, Hartridge, and Lythgoe { −0·15 'Method I' / −0·26 'Method II'<br>*Lower-case.*<br>In descending order of 'legibility':<br>dkmqhbpwuljtvzrofnaxyeigcs.<br>Correlation coefficient with:<br>(i) Sanford . . . . . +0·52<br>(ii) Roethlein . . . . . +0·56 |
| Sanford, E. C. (1888). | Rails carrying sliding box set (*a*) within easy distance, and moved by given amounts farther away, (*b*) too far away, and moved by subjects to limen.<br>Letters (Bold): Snellen optotypes size, D = 1·25, i. e. non-projectors were 1·8 mm. high.<br>Day lighting.<br>5 subjects: '2 quite far-sighted, 1 moderately, 1 normal, 1 near-sighted, but wore glasses.' | (i) Distance at which letters could be read.<br>(ii) Number of times letters read right or wrong.<br>(The accompanying judgement is the mean of the orders obtained in both these ways.) | *Lower-case.*<br>In descending order of 'legibility':<br>wmqpvyjf hrdgkbxlnu atizocse<br>'good' 'fair' 'poor'<br>Correlation coefficient with:<br>(i) Cattell . . . . . +0·52<br>(ii) Roethlein . . . . . +0·67 |

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## 8. *Legibility of Letters (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Finzi, J. (1901). | (i) *Subjects.* 8 adults, about 27 years old. 5 males, 3 females.<br>5 nationalities : 3 Dutch, 2 German, 1 Belgian, 1 Finn, 1 American.<br>Visual acuity not tested 'specially', but each subject at each session took what he felt to be his optimal distance from object. From 300 to 600 exposures were given each subject, who was given regular time-tables, and had to follow strictly daily physical routine for the duration of the experiments (4 days), and all of whom were in good health.<br>(ii) *Apparatus and method.* A practically noiseless tachistoscope. It had a black shutter with a white fixation-point, and moved horizontally from subjects' right to left across an opening 19 × 32 cm.<br>Duration of exposure 16·7 $\sigma$. Complete cycle from one exposure to the next : 10 secs. Subjects had to name letters they thought they had seen in correct order immediately after exposure.<br>(iii) *Material.* Isolated letters in 4 arrangements :<br>2 letters, 1 above the other<br>4 „ in 2 rows of 2<br>6 „ „ 3 „ 2<br>9 „ „ 3 „ 3<br>Letters were of a roman upper-case (type unspecified), measuring 3 × 3 mm., and typed on light, bright blue, transparent paper pasted on cardboard.<br>(iv) *Illumination.* Artificial, constant, independent of the room lighting. A gas burner behind the exposure card. | Errors. | *Upper-case.*<br>In descending order of 'legibility' :<br>PUAQXTDSEWMVYZHCNFLRGBKOI<br>(J is omitted.)<br>Correlation coefficient with :<br>(i) Cattell . . . . . −0·05<br>(ii) Kirschmann . . . . +0·10<br>(iii) Roethlein . . . . +0·19<br>(iv) Hartridge and Owen . . **+0·46** (H. and O. omit WIQMG)<br>(v) Banister, Hartridge, and Lythgoe { . +0·14 'Method I' ; . +0·10 'Method II' |

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| | | | |
|---|---|---|---|
| Javal, E. (1905). | None proper. Holding a book at different distances. | Distance from the eye. | *Lower-case.*<br>(i) Ascenders the most legible because the upper part of the letter which is the area fixated contains most of it. d, k, l the best; b, f, h, t the worst.<br>(ii) Next most legible are the 'simpler' letters, u, n, i. Type-written m is better than printed m.<br>(iii) g, j, p, q, y are 'good' letters, and v, w, z adequate as at present, but should project slightly above and below.<br>(iv) a, c, s the worst letters of all. |
| Hamilton, F. M. (1906). | Modified Cattell screen.<br>Exposure 0·021 seconds. 4–6 words.<br>(14–19 letters) type-written on cards and covering 45–60 mm.<br>Dark room; electric bulb of 16 candle-power on subjects' left. Adaptation time and practice were given.<br>Subjects educated. | Number of correct recognitions, taking account of different positions in a word they occupied (i. e. they would be placed first, last, middle, and penultimate). | *Upper-case.*<br>In descending order of 'legibility'.<br>ACDEILNOPRST (no more given).<br>He does not assert that it is a rigid 'legibility' order but gives it more as an example of method, and calls the element 'relative perceptibility'.<br>He says that he calculated the correlation coefficient between his complete list and Cattell's, but that it was practically zero. |
| Kirschmann, A. (1908). | Black letters on white ground, with black fixation-point. White on black, with white fixation-point. Monocular vision. Eye 1 metre distant.<br>Letters (isolated) tested along several meridians by being moved by small steps from periphery towards centre.<br>Simple 'block' letters were used. The accompanying list is the average of these for each case. | Peripheral distance from a fixation-point that letters could be read. | *Upper-case.*<br>In descending order of 'legibility':<br>AWILVXFYEZJTKDUSPBMRNOHGQC<br>(i) Angular letters more easily recognized in indirect vision than round letters.<br>(ii) Acute-angled more easily than right-angled.<br>(iii) Parallel vertical lines are a hindrance (e. g. in M, N, H).<br>(iv) Letters partly round and partly angular are more easily recognized than letters which are wholly curved.<br>Correlation coefficient with:<br>(i) Cattell . . . . −0·19<br>(ii) Finzi . . . . +0·10 (F. omits J.)<br>(iii) Roethlein . . . . +0·32<br>(iv) Hartridge and Owen . . +**0·53**<br>(v) Banister, Hartridge, and Lythgoe . . +**0·52** 'Method I'<br>. . +0·31 'Method II'<br>(Kirschmann himself states that his method of presentation has more in common with the normal reading process than has the tachistoscopic exposure, with which results his own cannot be compared.) |

## 8. *Legibility of Letters (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Dockeray, F. C. (1910). | 3 emmetropes, (i) electric light from 100 c.-p. bulb, and (ii) sunlight, reflected.<br>Letters in 10-point Roman Old Style on cards 35 cm. away. Distance between letters 10–80 mm.<br>Exposures (1,500 in aggregate) of 59 $\sigma$ (500 cards in varying order daily) through Dodge mirror tachistoscope with Cattell chronoscope. | Distance of 2 isolated letters on either side, from a fixation-point. | *Lower-case.*<br>Broad letters are the most legible; narrow letters and some tall ones, the least. |
| Roethlein, B. (1912). | See Roethlein, *Résumé* No. 4.<br><br>For (ii) the order is an average of 16 faces (see *Résumé* No. 4); 192 readings of each letter. | (i) Distance at which groups (unpronounceable) of lower-case letters could be read correctly.<br>(ii) Same as (i) but with isolated letters. | (i) 'The initial position in a group of letters is the most advantageous position for legibility; the final position comes next in order of advantage, and the intermediate or internal positions are least favourable for legibility.'<br>(ii) In descending order of 'legibility':<br>*Upper-case.*<br>WMLJIATCVQPDOYUFHXGNZKERBS<br>*Lower-case.*<br>mwdjlpfqyihgbkvrtncuoxaezs.<br>Correlation coefficient (upper-case) with:<br>(i) Cattell . . . . . +0·12<br>(ii) Finzi . . . . . +0·19<br>(iii) Kirschmann . . . . +0·32<br>(iv) Hartridge and Owen . . . **+0·43**<br>(v) Banister, Hartridge, and Lythgoe . . +0·24 'Method I'<br>+0·08 'Method II'<br>Correlation coefficient (lower-case) with:<br>(i) Cattell . . . . . **+0·56**<br>(ii) Sanford . . . . . **+0·67** |

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**Hartridge, H., and Owen, H. B. (1922).**

Distances from observer at which tests were made were 5 m., 7·5 m., 8·5 m., 10 m., and 12 m.

Subjects: 2, viz. Hartridge and Owen. Visual acuities fairly normal.

Letters used: Green's type. Limbs 1 mm. thick. Letters 5 mm. high, 4 mm. wide. Dull and bright daylight.

Errors made at different distances.

*Upper-case.*

In descending order of 'legibility':

LAJENHXPFZUTDYVKCBORS.

Correlation coefficient with:

| | | |
|---|---|---|
| (i) Cattell | . . . . | +0·08 |
| (ii) Finzi | . . . . | **+0·46** (Finzi omitted J) |
| (iii) Kirschmann | . . . | **+0·53** |
| (iv) Roethlein | . . . . | **+0·43** |

But Hartridge and Owen omitted, while Cattell and Kirschmann did not, WIQM and G.

| | | |
|---|---|---|
| (v) Banister, Hartridge, and Lythgoe | . | **+0·71** 'Method I' |
| | . | **+0·66** 'Method II' |

**Banister, H., Hartridge, H., and Lythgoe, R., (1925).**

'Method I.' Letters were block Capitals, Green's type, lying inside a rectangle 25 mm. high, and 20 mm. wide (except I, which was 25 × 5 mm.), with limbs 5 mm. thick. They were drawn 'in Indian ink on white mill-board.'

2 subjects (Hartridge and Lythgoe) of normal vision. Letters presented one at a time in irregular order. Artificial light. (A light source invisible to subject, and 2 mirrors.)

'Method II.' About 15 or 20 subjects of various (untested) visual acuities. Fixation mark provided. Daylight. The test objects as above.

'Method I.' 'The number of mistakes made in the recognition of the letters with prolonged observation, the letters at the eye making only a small angle.'

'Method II.'

'The number of errors made in tachistoscopic exposure.'

*Upper-case.*

In descending order of 'legibility':

'Method I.'

LJIAPTZFUEDXCNHKOWYRBMQSGV.

'Method II.'

JLPZEFDATUNHKBCIRWYSXOMVGQ.

Correlation coefficient between B., H., and L.

| and | 'Method' 'I.' | 'II.' |
|---|---|---|
| (i) Cattell . . . . . | −0·15 | −0·26 |
| (ii) Finzi . . . . . | +0·14 | +0·10 |
| (iii) Kirschmann . . . . | **+0·52** | +0·31 |
| (iv) Roethlein . . . . | +0·24 | +0·08 |
| (v) Hartridge and Owen . . | **+0·71** | **+0·66** |
| (vi) Banister, Hartridge, and Lythgoe, 'Method I' | | **+0·81** |

## 9. *Length of Line*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Weber, A. (1881). | 6 (educated) subjects : (*a*) silent, (*b*) loud reading (as a control) for 1 min. | Speed of reading. | (i) Minimum 100 mm. or 4 in.<br>(ii) Maximum 150 mm. or 6 in.<br>The latter is ' easier ' to read.<br>(iii) 100 mm. should contain 60 letters at optimum and maximum, and 50 letters at minimum. |
| Cohn, H. (1883). | | Fatigue on accommodation muscles involved by change in focus at centre of line and at ends. | 90 mm. or 3·6 in. optimum<br>100 ,, ,, 4 ,, maximum } best when gauge is 1·5 mm.<br>30 ,, ,, 1·2 ,, minimum<br>110 ,, ,, 4·4 ,, maximum for larger types.<br>' Shorter lines are easier to read because eyes have less far to move (per line).' |
| Fick, A. (188(5 ?)). | ? | ? | What is important is its ratio to interlineage. 40 : 1 is the optimum. |
| Javal, E. (1905). | Observations on patients. | Accommodation muscle strain involved in changing focus at centre of line and at ends (especially for myopes and young hypermetropes). | The line should not be ' too long '. |
| Dearborn, W. F. (1906). | Photography of eye-movements by pencil of light reflected from cornea. | Speed of reading and number of eye-pauses. For (v), progressive muscular retardation. | ' 75–85 mm. or 3–3·4 in., about 1/3 longer than New York daily newspapers, } with gauge of lowercase n of 1·5 mm.<br>combines a good many advantages.'<br>Short lines are better than long because :<br>(i) Words in line below are more likely to have sense-connexion while otherwise they distract attention. |

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| | | | |
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| | | | (ii) Motor habits help reading rate, and are more easily formed in short lines.<br>(iii) Refixations hinder, and are commoner in long lines.<br>(iv) But limit to shortness is distraction by hyphenating.<br>(v) Progressive muscular retardation makes long lines more fatiguing. |
| Ruediger, W. C. (1907). | Continuous reading (silent) at normal and at maximum speeds. Different sorts of subject-matter. | Amount read. | He favours a maximum of 75–85 mm., no matter what the subject-matter. |
| Maire, A. (1908). | | | The length of line should never exceed 100 mm. |
| Huey, E. B. (1910). | (i) 20 subjects (students) read 11 pages, one at a time, of an interesting novel, in ordinary surroundings, each page having about equal interest and similar arrangement of paragraphs, &c. The pages (all read at one session) were read (i) silently, normal speed and manner, (ii) ditto, but 'auditized', (iii) ditto, but 'motorized' without and with lip-movement, (iv) aloud, at normal speed, (v) i–iv as above, but at maximum speed.<br>(ii) (i) Type-written lists of words in non-sense arrangement. Columns of 1 word per line, with words of 2–16 letters, all the words in a column being of equal length, and with centre of each word above that of the next. Reading aloud at maximum speed. (ii) 300 words in sense-arrangement, the first 50 words in a column, the next, on separate sheet, in ordinary horizontal lines. (iii) Prose, 323 words long, read straight through in columnar arrangement, then in normal lines. (iv) Ditto, but silently. | (i) Ease in changing line.<br>(ii) Fatigue in accommodation.<br>(iii) Number of words read per fixation.<br>Amount that can be peripherally read either side of a given fixation-point. | Favours short rather than long lines.<br>100 mm. is certainly too long.<br>90 mm. is probably too long.<br>60 mm. (approx.) is, he thinks, the optimum.<br>'The line-lengths of modern newspapers are perhaps as near the optimum [for books too] as can at present be determined.' |

## 9. *Length of Line (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Brit. Assoc. Ctee. on influence of school-books on eyesight (1912). | | Accommodation strain. Picking up of new lines; frequency of change of eye direction. | * 'Very long is bad.'<br>'Very short is bad.'<br>For children over 12 [and for adults ?]: Maximum length, 93 mm. or $3\frac{2}{3}$ in. |
| Freeman, F. N. (1916). | 14 subjects (students). Eye-pauses counted by observation over subject's shoulder in mirror.<br>Daylight.<br>Silent reading at normal pace of (i) scientific, (ii) narrative text.<br>Type: Modern and Modernized Old Face.<br>Admits 3 sources of error:<br>(i) Counting movements instead of pauses.<br>(ii) Increasing accuracy of experimenter through practice.<br>(iii) Certain arithmetical errors.<br>[No visual acuity tests.?] | Speed of reading (silently) by time taken to read a given passage. | (i) Lines of 11-point type, 24 ems in length, were read slightly faster than those of 12 ems.<br>(ii) There are more reading pauses (though of shorter duration) in the lines of 12 than of 24 ems, and these involve a certain wastage of eye movements, since a certain number are solely due to the frequently recurring end of a line requiring a part of a fresh movement, and preventing the reader's true rhythm. |
| Ctee. on type faces and Govt. printing (1922). | None.<br>'The judgement of the trained human eye.' | Legibility and aesthetic. | For 12-point, 37 ems is too wide a line; instead, 2 columns of 11- or even 10-point are preferable. |
| Morison, S., and Jackson, H. (1923). | | Aesthetic appearance solely, presumably. | (i) 8 to 10 words per line are best.<br>(ii) Double columns should be used when more than 14 words occur per line. |

## 10. *Margin*

| | | | |
|---|---|---|---|
| Weber, A. (1881). | ? | ? | 'Superfluous.' |
| Cohn, H. (1883). | | | Is in favour of some; but no quantitative judgement. |
| Dearborn, W. F. (1906). | None; draws from R. MacDougall's experiment. | Influence upon accuracy of fixation. | Is in favour of margins, because reflex effect of peripheral colour-stimuli diminishes accuracy of |

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| | | | |
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| | | | fixation. Therefore the wider the margin, the more peripheral colour-stimuli will be kept out. |
| Amer. School Hygiene Assoc. (1911). | | Influence on eye-movements. | *For adults.* 'The margin should be sufficient so that the eye in the backward movement does not *swing off* the paper; and the inner margin should be wide enough so that the inner end of the line is not obscured by the curvature of the paper.' |
| Jacobi, C. T. (1912). | | Double page is the 'unit'. [On account of its alleged aesthetic superiority; but it appears to be only a typographical tradition which has never been scientifically tested.] | Inside margin should be narrowest. Top margin should be next in width. Outer margin should be next in width. Bottom margin should be widest. [(i) In a small book the result is an obviously inadequate dividing space between adjacent pages. (ii) Pages of books often do not lie quite flat, but curve away from eye on inside near hinge; and if a narrow margin here, part of the print is not at right angles to the eye.] |
| Brit. Assoc. Ctee. on influence of school-books on eyesight (1912). | None. *A priori* and a statistical inquiry. | Strain on (child's) growing eye. | * Good margins are restful and worth cost. |
| Jenkins, F. (1915). | | Strain on child's growing eye. | * 'The inner margin of the page should be wide enough so that when the book is open troublesome shadows are not seen, and words are not distorted by the curve of the inner part of the page.' |
| Ctee. on type faces and Govt. printing (1922). | None. 'The judgement of the trained human eye.' | For (i) Aesthetic.<br>For (ii) Fatigue in reading.<br>For (iii) Aesthetic legibility. | (i) Wide margins are important for display.<br>(ii) Optimum width depends chiefly on length and width of column or columns, and to some extent on position of reading-matter on the page.<br>(iii) No inter-column metal rules—white spaces only. |
| Legros, L. A. (1922). | | 'A white space should logically form the boundary between adjacent areas of print.' | Favours a slightly wider margin where a metal rule would otherwise be considered necessary. |

## 11. *Paper (and Ink).*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Babbage, C. (1827). | Inspection, and canvassing of people qualified to judge, with pages of figures set up on different shades of paper. | 'Votes' by individuals. | * (i) Some light colour better than white.<br>(ii) Yellow best (better than grey).<br>(iii) It may emerge that different colours are best for different people.<br>(iv) And that best colour for daylight is not best for 'candle'-light.<br>(v) The colour first chosen (i. e. Babbage's) unlikely *a priori* to prove ultimately the best. |
| Javal, E. (1880–1 and 1905). | | Fatigue. | Yellowish (= cream). Pure white is too strong a contrast and is fatiguing. The yellow should be one which excludes blue and violet rays. |
| Weber, A. (1881).<br><br>Cohn, H. (1883). | Investigation in schools. | Strain on child's growing eye.<br>Irradiation. | * Pale grey is best. It diminishes irradiation, compared with white.<br><br>(i) Pure white: yellowish paper causes bluish after-images and is therefore undesirable.<br>(ii) It should be of a thickness of not less than 0·075 mm. |
| Griffing, H., and Franz, S. I. (1896). | 10–12 words in 3 lines.<br>Cattell screen.<br>3 subjects (students).<br>Day and artificial lighting. | Degree of light-absorption. | In descending order of 'legibility':<br>(i) White.<br>(ii) Greyish.<br>(iii) Yellow.<br>(iv) Red.<br>Their theory is that hue as such is immaterial provided the colour of the paper absorbs a minimum light, and the order here is their intensity-order.<br>The surface should be matt. |
| Sack, N. (1896). | Investigation in schools. | ? | * The thickness should not be less than 0·075 mm. |
| Morris, W. (1898). | None. Empirical. | (i) Aesthetic.<br>(ii) Economic. | Paper should be:<br>(i) Hard.<br>(ii) Little ribbed.<br>(iii) Durable.<br>(iv) Unglazed.<br>(v) Handmade. |

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|---|---|---|---|
| Slefrig, S. (1905). | | | 'White letters on a dark page would be in many ways more legible than the converse.' |
| Huey, E. B. (1910). | | Degree of contrast. | (i) 'The paper should be pure white, but without gloss.'<br>(ii) 'Paper of a slightly yellowish tinge is probably not injurious, but pure white gives the greatest legibility.'<br>(iii) 'The print of one side must not show through to the other, and the printing must be so done that it will not affect the evenness of surface of the other side.' |
| Amer. School Hygiene Assoc. (1911). | | | *For adults.* 'The paper should be unglazed, free from shine, and opaque.' |
| Brit. Assoc. Ctee. on influence of school-books on eyesight (1912, and for (v) 1915). | Examination of school-books and school conditions. | (i) Strain on the (child's) growing eye.<br>(ii) Proportion of specular to diffuse reflection. | * (i) Cream is the best colour for average of all uses though white actually gives the best contrast.<br>(ii) It should have no glaze.<br>(iii) It should be hard pressed to avoid easy soiling or rubbed surface.<br>(iv) It should be thick to prevent print on back showing through.<br>(v) Glare is likely to be injurious when specular reflection exceeds 56 per cent. and diffuse reflection is less than 44 per cent. The risk is greater still in artificial light. |
| | | | *Paper and Ink.* |
| Roethlein, B. (1912). | (For general basis, see Roethlein, *Résumé* No. 4.)<br>Groups of letters in 9 faces were presented on each paper. 234 letters were employed. 2,808 readings were taken. | Distance from the eye at which nonsense (and unpronounceable) groups of lower-case letters could be read. | 'The quality and the texture of the paper is a much less significant factor than has been supposed—provided, of course, that the illumination and the inclination of the paper are such as to secure an optimal condition of light reflection from its surface.' Practically no difference was found between 'white coated book-paper' and 'rough-finished, very slightly yellowish paper'. Maximum individual difference between the two was 3 per cent. No unanimity or constancy of preference among individuals for either sort was found. |

## 11. *Paper (and Ink) (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| | | | *Paper.* |
| Hollingworth, H. L. (1913). | | | 'So far as acuity and legibility go there is no difference between the arrangement of white letters on a black ground and black letters on a white ground.' (But he explains preference for the latter by view that white is associated with space and blankness, black with objects; therefore black letters better than white.) |
| | | | *Paper and Ink.* |
| Report of the Ctee of Illuminating Engineers' Soc. (New York) on glare (1915). | | 'The brightness of the front face' is measured by 'the sum of the light reflected from this face and the light reflected back from underlying sheets.' (For iii.) 'A proper measure of the opacity of a paper is its density (= −log percentage transmission) and is a quantity proportional to the thickness. The specific density or the density per unit thickness is a measure of the quality of the paper material. Reflecting power and opacity of filler can be directly measured by its dryness, and the fineness of its particles. *Inks.* (i) Degree of contrast made with paper. (ii) Degree of specular reflection. | *Paper.* (i) 'From the reader's point of view print paper should possess a high (diffuse) reflecting power and but little gloss, and the print . . . on the back should not show through. Any glazing is entirely deleterious optically.' (ii) 'If the back reflection B is greater than 0·005 (= 1/2 per cent.), print on the back will show through quite perceptibly. No paper should be used except for special purposes for which B exceeds 0·02 (= 2 per cent.); if B is 0·01 (= 1 per cent.) the transparency is annoying.' (iii) Paper quality 'depends largely on the quality and the amount of the filler used. Good filler should possess high specific density and high reflecting power (filler used to give paper opacity). The ideal filler would be a mass of non-hydroscopic transparent crystals about 0·002 mm. in mean diameter and free from smaller or larger particles.' *Inks.* (i) Optically, glossy inks have lower diffuse reflecting powers than the mat inks, hence they are blacker and present a greater contrast with the paper. The mat inks are preferable only in the complete absence of glare.' (ii) 'The specular reflection of an ink depends on the matness of the paper on which it is printed. Specular reflection from ink is unobjectionable when below 0·005 (1/2 per cent.), and even glossy ink on a mat paper, not too fine grained, will not give serious glare.' |

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| Legros and Grant (1916). | | Degree of contrast. | 'As white as possible (with ink perfectly black and dead in colour).'<br>If paper surface is rough, 'it will take the surplus ink irregularly from the bevelled edges of the characters and thus produce an irregular appearance; on the other hand, excessive smoothness is inseparable from the (specular) reflection of light.'<br>In cases where much writing has to be carried out on forms printed on coloured paper, the tints selected should be light, and chosen from the green to the violet end of the spectrum. Pink and red paper are actually harmful to the sight.'<br>'Printing in light blue or green ink on white paper should be avoided as the contrast is insufficient.' |
| Sub-Ctee. of Permanent Consultative Ctee. on official statistics (1924). | None. Reference to decision by French War Office tables, 1891 [but no mention of Babbage]. | (i) 'Legibility.'<br>(ii) For mathematical tables and for long periods at a stretch: fatigue. | (i) Colour is important though uncertain as yet as to the best.<br>(ii) Light yellow probably best. |
| Lyon, O. C. (1924). | (i) Special 32 lb. paper slightly better than ordinary newsprint.<br>(ii) 22½ lb. catalogue paper, as in Chicago and N. Y. directories.<br>(iii) Ordinary 32 lb. Western Electric Co. paper, natural tint.<br>(iv) Half-tone newsprint used in cataloguing: specially high finish.<br>(v) Specially good newsprint used for cataloguing.<br>*Subjects.* Telephonists, clerks and business men. Time taken to find names in directory: (*a*) normally, (*b*) at limit of vision. 6-point type body.<br>'Most subjects appeared to have normal sight. Some wore glasses.' [No tests.] 'Normal daylight.' | (i) Time taken to find names in a telephone directory.<br>(ii) Judgement of 300 subjects as to appearance of pages in above. | * (i) No measurable difference between a white paper and four shades of buff-coloured newsprint. [The differences in colour between the four are not perceptible at a cursory glance.]<br>(ii) The white paper has greatest aesthetic appeal, and preferred generally.<br>(Not a general assertion on legibility, but only regarding telephone directories.) |



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## 11. *Paper (and Ink) (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Kerr, J. (1925). | | (i) Glare.<br>(ii) Strain on child's growing eye. | 'For the avoidance of glare the paper must be without gloss, so hard as to take a clean impression and not to be easily dirtied. It must be thick and opaque enough to prevent any shining through and not allow the pressure of types on the reverse side to mar the smoothness of the surface.' |

## 12. *Projectors*

| | | | |
|---|---|---|---|
| Babbage (1827). | Inspection of numbers of books of mathematical tables, &c. | Width of interlineage. | *Figures.*<br>Uniformity is better than variation in height because the figures then interfere less with the space between the lines. |
| Cohn, H. (1883). | | Ocular fatigue. | Is in favour of retention, and of their being of good length because their 'breaking of the monotony of the short letters is very beneficial to the eye as it prevents fatigue'. |
| Javal, E. (1880 and 1905). | None. | 'Confusability.' | *Figures.*<br>*A priori* is in favour of projectors: i. e. 0, 1, of same gauge as lower-case non-projecting letters:<br>3, 5, 6, 8 of same as ascenders<br>4, 7, 9 ,, ,, descenders<br>(2 is not mentioned). 'Figures 6 and 9 confusable with 0 if they have not projectors.'<br>(But if they have projectors, these parts are apt to get broken off, when same objection will apply.) |
| | None, strictly speaking. | Distance from the eye that letters can be read. | *Letters.*<br>I. *Ascenders* are the most legible letters; d, k, l the best, b, f, h, t the worst. The counter of b should be round, of h, square, f's cross-bar should project well to the right, t's to the left. t's head should be short.<br>II. *Descenders.* g, j, p, q, y are 'good' letters. Italicized |

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| | | | |
|---|---|---|---|
| | | | g, viz. *g*, bad as its bowl is too like q's. Better is g (though less simple) with bowl smaller. He would like to compress ascenders within the gauge of non-projectors, and to shorten considerably tails of descenders. |
| Sub-Ctee. of Permanent Consultative Ctee. on Official Statistics (1924). | | 'Eye-strain. | *Of Figures.*<br>(i) They distract the eye.<br>(ii) Liable to be broken off.<br>(iii) But by the irregularity of appearance which they produce, they facilitate keeping one's place. |
| | | 13. *Punctuation* | |
| Cattell, J. M'K. (1885). | | | 'Absolutely useless.'<br>Would substitute by different sized spaces. |
| Legros and Grant (1916). | | | They criticize Cattell's suggestion thus:<br>'In the opinion of the authors this proposal has many merits, but it is subject to one grave disadvantage. The spacing of the different lines of printed matter must necessarily vary in order to keep the length constant, and any such system would require that the space to denote the pause for the comma should, at least, be equal to a noticeable increase on the widest ordinary spacing, and a substantially larger maximum would be required to correspond to the long pause given for the period.' |
| | | 14. *Serifs* | |
| Hansard, T. C. (1825). | | Legibility' undefined, but not aesthetic effect. | Is opposed to extremely fine long serifs, but favours serifs generally speaking. |
| Javal, E. (1878–81 and 1905). | None in detail given. | (i) Irradiation.<br>(ii) Distance at which letters can be read. | (i) Favours them.<br>(ii) They should be thickish, short, triangular, not as in France 1750–1900, long, thin, and rectangular. If the latter, they meet, e. g., in n, and cause confusion with, e. g., u.<br>(iii) Long, thin serifs break easily.<br>(iv) Rounded best. Elzevir better than English. |

## 14. *Serifs (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Cohn, H. (1883). | | Irradiation. | Is in favour of them in Roman type. (He follows Javal here.) |
| Cattell, J. MK. (1885). | Gravity chronometer. Exposure for 1 $\sigma$ to 4 $\sigma$. Grey spot on black ground fixated before exposure. Day- and lamp-light; isolated letters exposed. | Time in which 50 per cent. could be correctly recognized. | Doubts utility 'of all ornaments. The simplest geometrical forms seem easiest to see.' |
| Sanford, E. C. (1888). | | Irradiation. | 'Serifs should be short and triangular, but as small as possible, the object being to overcome irradiation.' |
| De Vinne, T. L. (1900). | | | 'Sharp lines and dazzling serifs make all the light faces hard to read.' |
| Pergens, E. (1904). | Addition and removal, bit by bit, of those sections of a letter which together form the serifs; then counting the number of correct recognitions. | Distance from the eye that isolated letters can be read. | *Upper-case.*<br>(i) Serifs increase legibility in some cases but diminish it in most.<br>(ii) In any case they help only if on the 'external' parts of letters. |
| Slefrig, S. (1905). | | Irradiation. | Serifs should be triangular, not linear. |
| Brit. Assoc. Ctee. on influence of school-books on eyesight (1912). | None: *a priori* and a statistical inquiry. | Strain on (child's) growing eye. | * (i) Desirable, but must not be long: extensions sideways tending to form suggestion of a continuous line along top and bottom are bad. |
| Roethlein, B. (1912). | See Roethlein, *Résumé* No. 4. | Distance from the eye at which (i) isolated and (ii) grouped letters could be read correctly. | (i) The Sanserif face used by Roethlein to which she refers as News Gothic was 8th in legibility out of 16 faces in upper-case, and 1st in lower-case.<br>(ii) She composes from these 16 faces an optimum alphabet, selecting in the case of each letter the letter which proved the most 'legible' by her standard, no matter to which face it belonged, or whether each letter of her optimum alphabet came from a different face or not. In this alphabet no letter was from the Sanserif face in upper-case, but there were 9 in the lower-case. |

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| | | | |
|---|---|---|---|
| Parsons, J. H. (1914). | | Irradiation. | Favours them *a priori*. Visibility improved if they are triangular. |
| Legros, L. A. (1922). | | 'Specific legibility.' (For definition, see 2, Criterion of legibility.) | 'The idea that the serif is a mere ornament and not an integral feature of the familiar type faces used for ordinary reading matter . . . is far from being the case. The absence of serifs actually increases the resemblance between several sorts, e. g., i and l. Moreover, in square sorts, e. g., m, n, u, i, l, the presence of the serif ensures the provision of adequate white between the main-strokes of adjacent characters.' 'Excessive thickness [1] of the serif (as e. g. in French Clarendon) does not tend to increase legibility.'<br>[1] i. e. greater than that of the main-stroke. |

## 15. *Size of Type*

| | | | |
|---|---|---|---|
| Babbage, C. (1827). | Inspection of number of books of mathematical tables, &c. | | *Figures.*<br>'Clearness or facility of reading depends not only on size of type, but on the ratio of size of type to interlinear space.' |
| Weber, A. (1881). | 6 (educated) subjects. (*a*) Silent, (*b*) (as a control) loud reading for 1 min. Investigation in schools. | Speed of reading. Strain on child's growing eye. | (i) Minimum gauge 1·5 mm. Maximum 2 mm.<br>(ii) A gauge of more than 1·9 mm. does not increase speed of reading, and one of over 2 mm. hinders.<br>(iii) The ratio of gauge to interlineage is important. It should be 1·5 : 2 for Fraktur, and 1·75 : 2 for Antiqua. |
| Schneller (1884). | ? | ? | (i) The minimum width of main-strokes should be 0·3 mm.; of counter of n, 0·3 mm. |
| Fick, A. (188(5 ?)). | ? | (Physiological of some sort.) | The ratio of width of main-stroke to gauge of lower-case letters should be as 1 : 5. |
| Stettler (188(5 ?)). | | (Physiological of some sort.) | The ratio of width of main-stroke to gauge of lower-case letters should be as 1 : 5. |

## 15. *Size of Type (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Lamare (1892). | (i) Subject : himself.<br>(ii) Counting eye-movements by finger on lid.<br>(iii) Counting same also by attachment to eye making taps on a drum. | Number of letters that can be grasped by the eye in one reading pause. | (i) A tall letter is better than a shorter one.<br>(ii) He advises a large narrow letter. |
| Griffing, H., and Franz, S. I. (1896). | A hooded petroleum lamp (fairly constant) through ground glass 5 mm. × 5 mm. 20–30 minutes for eye adaptation. Cattell fall-screen. Letters in a row 1–4 words. 3 subjects. Length of exposure 1/2 sec. | Illumination threshold. | Most important factor is size of type.<br>(i) 1·5 mm. should be the minimum gauge.<br>(ii) Fatigue coefficient increases slowly from a gauge of 6 mm. down to one of 1·6 mm., and increases quickly below that. |
| | | | *Lower-case.* |
| | (i) Where amount read was measured, matter consisted of 622 words in a passage in the Bible.<br>(ii) Cattell fall-screen (worked by subject). Exposure time 1/2 sec. Hooded petroleum lamp (fairly constant) through ground glass. 3 subjects, 20–30 mins. for eye adaptation. | Ratio of percentage of words read of total exposed in small type to ditto in large. | (i) About 50 per cent. of amount read in large type (i. e. gauge 1·6 mm.) was read in small type (i. e. gauge 0·8 mm.).<br>(ii) Three-quarters the time was needed to read a given amount in the large type (i. e. 1·6 mm.) as in the small type (i. e. 0·8 mm.). |
| Pergens, E. (1904). | By adding on sections at a time to the limbs of isolated letters. | Distance from the eye that isolated letters can be read. | *Upper-case.*<br>Increasing gauge increases legibility of (i) those letters formed solely of straight lines, not containing right angles, viz. V, M, W, Y, X, N, Z, K, A ; and (ii) up to a point those letters formed solely of straight lines containing only right angles, viz. I, L, E, F, T, H. |
| Javal, E. (1905). | None, strictly speaking, as far as is given in his book. | (i) Distance from the eye that printed page can be read. | *Lower-case.*<br>(i) Size of type is the most important factor in legibility.<br>(ii) 5-point should be used only when the counters are at least equal in width to the main-strokes.<br>(iii) 10-point optimum for presbyopes.<br>(iv) 8-point optimum for myopes.<br>(v) 9-point is sufficiently big in general. |

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| | | | |
|---|---|---|---|
| Huey, E. B. (1910). | Summary of other investigators' views. | Speed of reading and fatigue. | (i) 'The size of type is perhaps the most important single factor in legibility.'<br>(ii) 'Preferably the height of the lower-case non-projector should be somewhat above the minimum of 1·5 mm. on which investigators are generally agreed, but not much above 2 mm.' |
| Amer. School Hygiene Assoc. (1911). | | | *For adults.*<br>Minimum height of lower-case letters should be 1·5 mm. |
| Roethlein, B. (1913). | See Roethlein, *Résumé* No. 4. | Distance from the eye at which isolated letters could be read correctly. | 'The legibility of a face undoubtedly increases directly with the increase in the size of a face.' |
| Freeman, F. N. (1916). | 14 subjects (students). Type Modern or Modernized Old Face. Length of line, 24 ems. Texts: (i) scientific, (ii) narrative.<br>Eye-pauses counted by observation of subject's eye in mirror. Daylight. Admits 3 sources of error: (i) counting movements instead of pauses of eye; (ii) increasing accuracy of experimenter through practice; (iii) certain arithmetical errors. [No visual acuity tests ?] | Speed of reading (silently), (i) at normal, (ii) at maximum speed, by time taken to read a given passage. | (i) Type of 7-point was read more rapidly: (i) on the average, and (ii) by 8 out of 14 subjects, than 11-point.<br>(ii) 'The finer type seems to allow somewhat greater scope of fixation, but the number of fixations per second does not increase.' |
| Judd, C. H. (1918). | Kinetoscopic photography of eye-movements. The type face is reproduced but not designated. It is a sort of Old Face with very slight serifs, and a high degree of contrast. He used 3 sizes: 22-point, 11-point, and 4½-point (?). 6 lines of narrative (reproduced) were read silently by 3 subjects; these were graduate students. | Duration and numbers of eye-pauses. | The rate of reading and span of recognition are only slightly altered by doubling or halving the body-size of a face.<br>Slightly more influence was exerted by halving than by doubling the size. |
| Ctee. on type faces and Govt. printing (1922). | 'The judgement of the trained human eye.' | | 'Legibility depends not on face-size alone but on the proportion of face-size to interlinear space.' |

## 15. *Size of Type (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Parsons, J. H. (1922). | | Amount grasped by the eye per glance. | He is certainly not opposed to condensed letters; on the contrary he thinks that there may be an advantage in them. |
| Morison, S. (1924). | | Aesthetic and compactness of appearance of the whole line and/or page. | *Upper-case.* The upper should be slightly less high than the lower-case ascender. |

## 16. *Spacing*

| | | | |
|---|---|---|---|
| Weber, A. (1881). | 6 (educated) subjects. (*a*) Silent, (*b*) loud reading (as a control) for 1 min. | Speed of reading. | Optimum (and maximum) number of letters per line of 100·3 mm.: 60.<br>Minimum number of letters per line of 100·3 mm.: 50. |
| Cohn, H. (1883). | 'Distinctness' of individual letters. | | (i) The white between adjacent letters should be wider than that between the main-strokes of a letter as 'every letter stands out more distinctly by isolation'.<br>(ii) With letters of 1·5 mm. gauge, the space between the main-strokes should be 1 mm., and between words 3 mm.<br>(iii) There should be not more than 44–46 letters per line of 94 mm. |
| Schneller (1884). | ? | ? | The minimum width of counters should be 0·3 mm. |
| Griffing, H., and Franz, S. I. (1896). | 2 kinds of Roman, a German and a Block (u. c.) type. Cattell screen. 12 experiments with 3 subjects. Petrol hooded lamp of 0·02 candle-power. 1–4 words exposed at a time. | Fatigue. | No quantitative general judgement.<br>They imply that an increase in spacing would be an improvement (though their own experimental results are negative), but that the economics of printing probably make it inadvisable. |
| Sack, N. (1896). | Investigation in schools. | ? | * (i) The space *within* the letters between the vertical strokes should not be less than 0·5 mm.<br>(ii) The space *between* the letters of a word should not be less than 0·5 to 0·75 mm. |

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| | | | |
|---|---|---|---|
| | | | (iii) The space between the *words* should not be less than 2 mm.<br>(iv) The number of letters per running centimetre should not be more than 6 or 7. |
| Morris, W. (1898). | None ; empirical. | Aesthetic. | There should be minimum and equal spaces between words (i. e. no ' rivers '). |
| Burgerstein, L. von, and Netolitzky, A. (1902). | Investigation in schools. | | (i) ' The space between the *letters* of a word should be greater than the distance between two neighbouring ground strokes of a letter.'<br>(ii) The space between the *words* should not be less than 2 mm.<br>(iii) The number of letters per running centimetre should not be more than 6 or 7. |
| Javal, E. (1905). | Clinical experience. | Fatigue, i. e. strain on accommodation muscles, particularly for myopes and young hypermetropes. | Letters should not be ' too widely ' separated, but he thinks ' wider ' spacing (i. e. than in use in France in 1905) between letters increases legibility (i. e. distance from eye at which book can be read). He thinks that one reason why English is more legible than French is because, words being shorter, there is more white space per page.<br>Round letters need less space than straight letters, because of irradiation. |
| Huey, E. B. (1910). | | Speed of reading. | (i) ' There is probably little to be gained by increasing the distance between the letters (of a word) beyond that which is usual in the better printed books of the present time.'<br>(ii) ' When the same number of words was printed in fewer lines of the same length and the same size of type, they were read faster in just the proportion that the lines were fewer.' |
| Amer. School Hygiene Assoc. (1911). | | | *For adults.*<br>(i) Spacing between letters : 0·5–0·75 mm.<br>(ii) Minimum space between words : 2 mm. |
| Brit. Assoc. Report of Ctee. on influence of school-books on eyesight (1912). | *A priori*, and a statistical inquiry. | Strain on child's growing eye. | * (i) Unusual separation of letters should be avoided.<br>(ii) Number of letters per running inch should not on the average exceed 13–14 (= 52–56 per 100 mm.). |

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## 16. *Spacing (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Parsons, J. H. (1914). | | Irradiation. | (i) Round letters (e.g. two 'O's') when adjacent should actually have less space on either side of them than straight letters.<br>(ii) Inter-letter space should not be less than that between the main strokes of the n. |
| Legros and Grant (1916). | | | (For children's school-books.)<br>(i) 'The a–z length should not be less than 13 ems.'<br>(ii) 'The normal space between words should not be less than the en quad.' |
| Sub-Ctee. of Permanent Consultative Ctee. on Official Statistics (1924). | | Fatigue. | *Figures.*<br>(i) There should be 'adequate' spacing between each figure (and line).<br>(ii) To accomplish this, a large body-size should be used, but a large enough one is impossible with only royal octavo page. |

## 17. *The Ideal Type*

| | | |
|---|---|---|
| Javal, E. (1878–81 and 1905). | (i) Distance from the eye that pages of print can be seen.<br>(ii) Fatigue on accommodation muscles. | [Illustrations of the following are to be found in Javal's book.]<br>a. Should be like inverted r, ɹ (i.e. upper half of present loop gone).<br>b. Should have round counter, smaller than d's.<br>c. Should have slightly larger gauge than 'straight line' letters, and have open eye-piece, c (ancient), or ć (Cohn), not c.<br>d. Counter rounder and bigger than b's.<br>e. Gauge slightly greater than 'straight line' letters, and cross-piece level or oblique: eye-piece open.<br>f. Cross-bar should be short and thick and project well to the right (distinct from t).<br>g. Short descender: not italicized *g* but ɡ (though less simple, i.e. height of bowl less than square sorts), and an ellipse on horizontal axis. Abolish acute angle curl on right top corner.<br>h. Counter should be square.<br>i. Dot not much thicker than main stroke and high up. |

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j. Short tail.
k. As it is.
l. „ „
m. Condensed like type-written m.
n. As it is.
o. Gauge greater than ‘ straight letters ’.
p. Counter smaller than q’s ; short tail if any ; prefers none.
q. Counter larger than p’s ; short tail if any ; prefers none.
r. The tail-dot should be high up (to keep r clear from n) and not dropped low.
s. Larger and angular.
t. Cross-bar well to the left, short and thick. Horizontal lower serif at foot is best ; but at least minimize hook, because it is inevitably thin, which is bad.
u. Compressed (?), very square, when very small type. Symmetrical serifs.
v. Slightly greater gauge than ‘ straight line ’ letters.
w. „ „ „ „ „ „ „
x. As it is.
y. Keep tail short.
z. As it is.

(When Javal says gauge of certain letters should be greater than that of straight line letters, he intends the former to project slightly above *and* below others.)

(i) Upper case desirable.
(ii) Boustrophedon[1] might be an improvement.
(iii) Cuneiform likewise for certain confusable pairs.
(iv) Favours (for upper-case) some contrast by use of main strokes.
(v) Therefore favours serifs too : thick, short, and triangular.
(vi) No leading.
(vii) Black ink (need not be ‘ perfect ’ black) on yellow paper.
(viii) Small books—so as to permit head movements. (Then black and white after-images will fall on same part of retina and cancel, otherwise fatigue is caused.)
(ix) Fifteenth-century style is best, and
(x) Distinguishing qualities should be in the upper halves.

[1] = Direction of reading being left to right and right to left in alternate lines.

## 17. *The Ideal Type (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Cohn, H. (1883). | | Strain on child's growing eye. Ability to read fluently 20 in. away. | The minimum gauge should be 1·5 mm. The minimum thickness of limbs : 0·25 mm. Characters should have serifs. Ascenders and descenders should be retained. In Fraktur (i) n should be broader than u. (ii) Lower-case c should have the tail-dot inside-out : c̣. |
| Cattell, J. M'K. (1885). | Gravity chronometer exposure for a few $\sigma$ only (1–4). Grey spot on black ground fixated first.<br>Day- and lamplight used.<br>Isolated letters exposed.<br>[Slit too narrow for projectors to be entirely visible at a given moment.] | Time in which 50 per cent. of isolated letters exposed could be recognized. | (i) Use of 2 kinds (upper and lower case) of letters probably useless.<br>(ii) All ornaments hinder legibility.<br>(iii) The simplest geometrical forms seem easiest.<br>(iv) Lines must not be too thin. ('We seem to judge the letters from the thick lines.')<br>(v) Doubts utility of using both thick and thin lines.<br>(vi) Different-sized spaces instead of punctuation.<br>(vii) He would abolish C, Q, and X and use ʌ for l and ɩ for i. |
| Griffing, H., and Franz, S. I. (1896). | (i) 12 observers reading a passage of 322 words in the Bible.<br>(ii) 30 observers reading 1–4 words exposed at a time in a Cattell screen.<br>Daylight and petroleum hooded light of 0·02 candle-power through ground glass screen. | Illumination threshold for fatigue. Amount read. Time taken. | (i) 11-point or 1·5 mm. gauge minimum was to be used.<br>(ii) Thickness of limbs more important than form of letters.<br>(iii) Complexity within limits seems to have no important decided effect on legibility.<br>(iv) Spacing to be, if anything, on wide side (no quantitative judgement).<br>(v) Leading is desirable (no ratio figures given).<br>(vi) Paper : white is best. |
| Morris, W. (1898). | None ; empirical. | Aesthetic effect. | (i) Simplicity—no excrescences.<br>(ii) Broad.<br>(iii) Rather thick.<br>(iv) No thick-and-thinness.<br>(v) No leading.<br>(vi) No 'rivers', but minimum and equal spaces between words.<br>(vii) Paper hand made ; to obtain that it should be hard, little ribbed, unglazed, and durable. |
| Slefrig, S. (1905). | | | *Lower case.*<br>a. Should be like inverted v or small capital A, or of ordinary design, but condensed, tall, and with long loop at foot of right limb.<br>f. The ascender should be long and heavy. |

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Maire, A. (1908).

Distance from the eye at which letters can be read.

i. The dot as high above stem as possible. Both should be (equally) thick.
j. The descender should be long and heavy.
n. The opening at the bottom (only) should be widened.
s. The lower-case design should be discarded, and a new form of f should be substituted.
u. The opening at the top (only) should be widened.

*Upper case.*

C and G. 'Serifs alone distinguish these letters'; it would therefore be wise to discard the upper serif in G.
H. The cross-bar should be thick to avoid confusion with U, and serifs discarded to avoid confusion with U, T, and D.

*Lower case.*

[Illustrated in his book.]

a. Bowl vertically compressed, and entirely in lower half.
b and d. Tall ascenders.
c. The top end of the letter is to the *left* of vertical centre line. Both ends are sliced off obliquely.
e. Oblique cross-piece.
f. Cross-piece extends well to the left. Top overhangs considerably.
g. Large thick tail, in horizontal ellipse.
h. Tall ascender. Serif on left main stroke only. Right, trifle shorter, ends in curved point.
i. Dot half-way up height of full ascenders.
j. Tail almost straight. Ends in a point without tail-dot.
k and l. Thick and with full tall ascenders.
m and n. No serifs on right-hand vertical strokes. These as in h.
o. No hair lines. Vertical ellipse.
p. Loop slightly open at bottom. Long descender.
q. Loop slightly broader than p's but closed. Long descender.
r. Arm does not drop. End of arm sliced as in c.
s. Top loop very small, lower loop large, and tail extends far to the left.
t. Cross-bar extends well to right. Very short tail-loop.
u, v, w, x. Thick.
y. Long tail. End horizontally sliced instead of tail-dot.

[The whole face bears a general resemblance to Javal's, but differs in many details. There is less contrast and projectors are longer.]

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17. *The Ideal Type* (*continued*)

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Brit. Assoc. Ctee. on influence of school-books on eyesight (1912). | None. Statistical inquiry. | Strain on (child's) growing eye. | * (i) Paper should be unglazed, hard pressed, thick, and cream-coloured.<br>(ii) Ink should be 'good' black, evenly distributed, of one colour.<br>(iii) Double columns bad for ordinary work.<br>(iv) No condensed type, but broad and square. No 'excessive contrast of thick and thin.<br>(v) No heavy type if at cost of reducing counters.<br>(vi) Serifs, but not long ones.<br>(vii) Italics should be rare.<br>(viii) Leading is wasteful.<br>(ix) Some indentation may help reading rhythm.<br>Minimum dimensions for children over 12 :<br>For height, 1·58 mm. = 1/16 in.<br>a–z length, 47 mm.<br>Interlineage, 1·8 mm.<br>Maximum number of lines per 100 mm. = 24.<br>Maximum length of line, 93 mm. = $3\frac{2}{3}$ in (22 [pica] ems).<br>(The bulk of the Ctee.'s recommendations are intended primarily for school-books, but some are not excluded from application to ordinary printed matter.) |
| Legros and Grant (1916). | | | They suggest the addition of two new letters :<br>(1) To replace th (and Th and TH).<br>(2) To replace ng (and NG).<br>For 1. Their own design is (lower case) an h with a cross-bar starting from just below the top serif, and extending the whole width of the letter ; (upper case), the cross-bar of a capital T placed across the top of a capital H.<br>For 2. (Lower case) a g with a somewhat flattened and simplified tail-loop and a bowl not quite closed at the right-hand side, this making it like an n ; (upper case) a G with the eye-piece closed by a vertical hair-line and the top half of oblique line of N from left top corner, to meet bottom of hair-line. |

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| | | | |
|---|---|---|---|
| Govt. Ctee. on type faces, &c. (1922). | None. 'Judgement of the trained human eye.' | Aesthetic effect and 'legibility' (undefined). | (i) Simplicity.<br>(ii) Broadness rather than compression.<br>(iii) No undue thick-and-thinning of serifs and strokes.<br>(iv) Counters not less than a certain (unstated) minimum.<br>(v) Adequate proportions without leading, hence<br>(vi) Old Face and Old Style better on the whole than Modern Face.<br>(vii) Margins of importance: depend on size of column(s) and position of matter and heading.<br>(viii) No intercolumn metal rules. |
| Morison, S. (1924). | | (i) Aesthetic appearance.<br>(ii) Historic origins from earliest times. | (i) The essential form should correspond to that handed down.<br>(ii) The letters should compose agreeably into words.<br>(iii) Lower-case letters should be homogeneous in line and colour.<br>(iv) Upper-case letters should merge as easily as possible with the lower-case.<br>(v) Upper-case gauge should be at most slightly less than that of lower-case ascenders. The capitals must not be conspicuous and 'spot' the page.<br>(vi) No extreme contrast of thick and thin. |

## 18. *Thickness of Limbs*

| | | | |
|---|---|---|---|
| Javal, E. (1880 and 1905). | | | Must be greater than if letters were designed solely for the perfect eye, so as to suit all conditions. Limit is when letter begins to lose its shape. |
| Cohn, H. (1883). | | Eye-strain in children. | * Minimum for main strokes 0·25 mm. in school-books. Physiologically, thick strokes are best, as 'the picture on the retina is broader and therefore can be read more easily'. |
| Schneller (1884). | | ? | The minimum width of main strokes should be 0·3 mm. |
| Fick (188(5 ?)). | | (Physiological, of some sort.) | The ratio of width of main stroke to gauge of lower case should be as 1 : 5. |
| Stettler (188(5 ?)). | | (Physiological, of some sort.) | The ratio of width of main stroke to gauge of lower case should be as 1 : 5. |

## 18. *Thickness of Limbs (continued)*

| *Author and year.* | *Experimental basis.* | *Criterion.* | *Judgement.* |
|---|---|---|---|
| Griffing, H. and Franz, S. I. (1896). | Roman (lower case):<br>(*a*) Uniformly thick.<br>(*b*) Thick and thin.<br>German (lower case).<br>Block upper case:<br>(*a*) Thick.<br>(*b*) Thin.<br>Cattell screen. 3 subjects. Petrol hooded lamp of 0·02 candle-power. 1–4 words exposed at a time. Length of exposure 1/2 sec. | Fatigue through illumination threshold. | 'Increased thickness of limbs even when not throughout all the lines of a letter, increased the legibility of the faces tested.' |
| Sack, N. (1896). | Investigation in schools. | ? | The thickness of the vertical strokes of the lower-case letters should be 0·3 mm. |
| Morris, W. (1898). | | Aesthetic effect and 'legibility'. | The limbs should be 'rather' thick. |
| Brit. Assoc. Ctee. on influence of school-books on eyesight (1912). | | Area of counters. | * (i) Heavy face bad in so far as it reduces counters.<br>(ii) 'Slight thickening of lines does not matter.' |
| Amer. School Hygiene Assoc. (1911). | | | The minimum width of main stroke should be 0·25 mm. |
| Roethlein, B. (1912). | See Roethlein, *Résumé* No. 4. | Distance from the eye at which isolated lower-case letters could be read correctly. | 'It would appear that the optimal breadth of line for (10-point) lower-case letters . . . may be in the neighbourhood of 275 to 333 microns. It seems to be evident[1] . . . that, when the breadth is reduced much below 250, or is increased in the neighbourhood of 450 (microns), 10-point letters become relatively illegible.' |

[1] See her Table XIII.

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# APPENDIX 1 c

## Index to Authors appearing in Historical Subject-*Résumés*

(The numbers following the names refer to *résumés*, not pages)


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# APPENDIX 2 A

## Type-Faces used in the Experiments

'Type No. 1'

LANSTON MONOTYPE SERIES No. 2 — Old Style

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

'Type No. 2'

LANSTON MONOTYPE SERIES No. 7 — Modern Extended

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

'Type No. 3'

LANSTON MONOTYPE SERIES No. 101 — Imprint Old Face

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

'Type No. 4'

LANSTON MONOTYPE SERIES No. 39 — Modern Condensed

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

'Type No. 5'

CASLON SERIES No. 23 — Modern

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

'Type No. 6'

LANSTON MONOTYPE SERIES No. 161 — Old Style Antique

**ABCDEFGHIJKLMNOPQRSTUVWXYZ**

**abcdefghijklmnopqrstuvwxyz**

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'Type No. 7'

LANSTON MONOTYPE SERIES No. 17 Cushing

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

'Type No. 8'

STEPHENSON & BLAKE SERIES No. 10 Lining Grotesque

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

## APPENDIX 2B

### Nonsense Material

*Vowelless.*

Rfn htwh hftr cfw hsmh wf t gds pn stsf nl slhvg rhns hrltt cnl vcnn trc gnt c fr. Hw ntr hvsg rh, wvh, hr htswh spn tgsrv strn llws, wn drhwsv ntrd h tprgh s ft rhwsc, htlrs tt hsht rwn wbkchn ctsd lb rfcr. Thsbc hw s khct stw dm n shn gpw rfrln g prd, ndlt, hnt sspt snltf tst sprl l rc gncn frt r nnv sns nf mth wn csh mtsd gst rbn t hmtn. Dw stnh tth sghht lht sp csnc dtr nsk fds nrd, tsms hnth lbttp rpc rnts ndd hfn dshcp tshl c nrggn crtsf nffr cr rrn tbk c wsf hr hdt fclft tb rvc m sfr shm trt j rf wns d nctps nc rrdn c. Htr cn gcs wr, nth rdss, mtrlz gt nrwp ttd, nth t gts vrrm ch tsc lhd tsmn, td htw h lvn fmtns dl cnb t ldr ts, rsf w hm nts lw ndm thg twlt drbb pl ssm tdth. Pllr, phl, dds dr kll ndnv hg tsgn rnrv drt ns rtdc sthvw ntrrd sn c rftf hr. Tll fhp tg snt crwt nnm, dn tsm ftmh vhb nsll crs t ntm, sthhr vv smh pt hnwt, d nppt r cnf, h ttrsl fht rg tcnf rc. Wng t rrsn cdl nntt htkth ssm tf hts tg gpn thd ttw vth hs dl tmts bth tc s cl gn wh l trtn tl ldw sh chs srp nb lr f npp rw ctsh. Sth tr fc fdn lt pxd tcth t wh nt rvt hs pdr ftm stf stcr sst tf rff wl mh v nbrr gd n. R fst nk lt thl mgn wts clf s prs mtsn chs sth, sn llfg nl shl bdw ll dg tth p rph dnr. Ttdn ft s dnh t dr ntn fht rv nrj hr hnst vm trf cm rcm ds npr, tn df stp lss prp cds prt rfn ht n.

*With vowels.*

betop desic tra, dulowc feaft metmes sve. Puthen botinoi mofas mimilra tyajmo ir, imed sopas awal eothu yirtimo, quonin eftsios fesb ge ragridn cudnoc, tiquesit sakely ilot bewgron sa thirg; orf ineseth sesac cuilb pinopin menosan, athet steb, pemos enople'n siopi wofi shagit odorab drof oerth pelpo; heewil yerv netoi ttesod toneen navem tath; pethluec, thwib thotsm preecf tecnerei, pidnis gnasif revo theaple reorus nevoc encien ofesoth wheso cudom tyeth erusnec, dancos niderign yolni tweron phrenc feerec. Teehar enamy whocodn sereas yanijnu rotemth sveels yadnuc tonc dwich heyth tavead fistaseor, darense nitasn aneogartu torethil feesignas; asin ogiler sighf nefoser oth, togib hewnedarg chwith gidnar dregis relth esiougi, thanceb wokn toren totarth yethils dregad hirs sgelenif, prybs egnistirehit inelbanim woba pishor rordeec. Buitereth nos yartip webnete



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fethlig nefoap noers rof ish nwopo diniano nefthegli ofaeron whoth sifof adented hishol gidn itno ; eromth wanene teb teh erides fofiathe tokeapur etos, dathner desi eofethigt whorrenk topetic. Pandesar ton'sti mesash chwis oniarl cucep nercno ashis ropoini esrup hins. Yetisea srof ganyono etimani aneliad pecliab, huwich sevale fetheer mod chand fooice slaudvini dilnila niatrecun srettam debrutis nud, yandon lyrequis remeth abt ositna mof moders fonoc twiduch claserinuvix ecneep reshanc demnedo. Whub reet sharthee nebeese nualcip chwib thes yanush mithil itos pitshor snec ? Wheron seod pelcith buelbuort.

## APPENDIX 3

LIST OF (1) BOOKS AND ARTICLES, WITH THEIR AUTHORS, WHICH FORMED THE MATERIAL FOR THE TEST-SHEETS, AND (2) EXPERIMENT-SERIES AND TEST-SHEETS FOR WHICH EACH EXCERPT WAS USED.

Printed at the Oxford University Press

| *Experiment-series.* | *Type-face No.* | *Sheet No.* | *Title, page-number, edition, and author of book, or article.* |
|---|---|---|---|
| A | 1 | III | Golf. Excerpt from *The Times*, 27 April 1923, p. 8. |
| | | | Contentment. Excerpt from *The Times*, 28 April 1923, p. 11. |
| | | IV | Religious Terms. Excerpt from *The Times*, 28 April 1923, p. 13. |
| | | | Preface to *170 Chinese Poems*. A. Waley. (2nd ed., 1920, p. 19.) |
| | | V | *Jude the Obscure*. T. Hardy. (Pocket ed., 1920, p. 1.) |
| | | | *Education for Liberty*. Kenneth Richmond. (1918, p. 55.) |
| | | VI | *Decline and Fall of the Roman Empire*. Gibbon. (New ed. in 12 vols. 1813, Cayell & Davis, Strand, vol. ii, Chap. XV, p. 265.) |
| | | | *A Revision of the Treaty*. J. M. Keynes. (1st ed., 1922, p. 4.) |
| | | VII | *The Pretty Fable* from *Collected Parodies*. J. C. Squire. (2nd ed., p. 206.) |
| | | | *The Golden Draught* from *And Even Now*. Max Beerbohm. (2nd ed., 1921, p. 117.) |
| | | VIII | *Marcus Aurelius Antoninus to Himself*. (Trans. G. H. Rendall, *Golden Treasury*, ed., 1920, p. 5.) |
| | | | Fashions for Travelling. Excerpt from *The Times*, 30 April 1923, p. 15. |
| | | IX | *Letters from John Chinaman*. G. Lowes Dickinson. (March 1911, p. 32.) |
| | | | *Anticipations*. H. G. Wells. (Cheap ed., 1914, p. 126.) |
| | | X | Housing. Excerpt from *The Times*, 1 May 1923, p. 7. |
| | | | Taxation of Betting. Excerpt from *The Times*, 11 May 1923, p. 16. |
| | | XI | *English Literature and Society in the Eighteenth Century*. Leslie Stephen. (1910, p. 2.) |
| | | XII | *Ibid.* |
| | | | *Human Nature in Politics*. Graham Wallas. (2nd ed., 1910, p. 59.) |
| B | 1 | IV–VIII | See above. |
| C | 2 | XIII–XVI | *Human Nature in Politics*. Graham Wallas. |
| D | 3 | XIII–XVI | *Ibid.* |

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Printed at the Cambridge University Press

| *Experiment-series.* | *Type-face No.* | *Sheet No.* | *Title, page-number, edition, and author of book, or article.* |
|---|---|---|---|
| Check-tests | 1 | XLIII–LI | *Essay on Liberty.* J. S. Mill. (Chap. IX.) |
| 1 | 1 | III–VII | See above, Oxford University Press. |
| 2 | 2 | XIII–XVI | " " " " |
| | | XVII | *Essay on Liberty.* |
| 3 | 3 | VIII–XII | See above, Oxford University Press. |
| 4 | 4 | XVIII–XXII | Preface to *The Doctor's Dilemma.* Bernard Shaw. (3rd imp., 1913, p. xiii.) |
| 5 | 5 | XXVIII–XXXII | *Essay on Liberty.* |
| 6 | 6 | XXXIII–XXXVII | *Ibid.* |
| 7 | 7 | XXXVIII–XLII | *Ibid.* |
| 8 | 8 | XXIII–XXVII | Preface to *The Doctor's Dilemma.* |

## APPENDIX 4 A

### Glossary to Typographical and other Terms used in this Report

Body. The metal shank or stem which carries the face. Measurements of type-body refer to the height of its cross-section.

Case. Upper-case (letters) (u.c.)—capital letters.
Lower-case (letters) (l.c.)—small letters.

Colour. Refers to the colour of the ink. By good colour is meant a dead black of even intensity.

Counter(s). The internal space(s) in a letter.

Face. (i) The letter-shape which projects from the end of the metal stem. (ii) A term 'generally applied to any fount of type when describing its features' (Legros and Grant).

Gauge. The height of the printed letter.

Indentation. The space left in a line of less than full length.

Leads. Thin strips of metal used for separating lines of type and increasing the amount of white between them.

Point. A unit of measurement for type body-size. One point = 0·013837 inch.

Rivers. Channels of white space that catch the eye, running down the page, formed by the ends of words in successive lines coming directly or almost directly below one another.

Serifs. Projections at the upper or lower ends of the mainstrokes of a letter.

Threshold (= Limen). The minimal stimulus which will excite a relevant response.

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## APPENDIX 4 B

### List of Abbreviations

| | |
|---|---|
| $\mu$, or micron | = 1/1000th of a mm. |
| $\sigma$, or sigma | = 1/1000th of a second. |
| M.V. | = Mean Variation. |
| P.E. | = Probable Error. |
| V.A. | = Visual Acuity. |
| f.-c. | = foot-candle(s). |
| m.-c. | = metre-candle(s). |
| c.-m. | = candle-metre(s). |

## APPENDIX 5 A

### Explanatory Note to Table of References

The literature primarily concerned with the core of this research, namely, the comparative legibility of type-faces and the influence upon legibility of various typographical factors, is far from large, especially if scientific works only are taken into account. On the other hand, the literature on various topics connected with this core is enormous. On one side lies the whole field of printing in its technical, artistic, and historical aspects ; on another, that of psychology, including pedagogy (e. g. the teaching of spelling, reading, and writing), and pathology (e. g. alexia, aphasia, &c.), and especially those branches dealing with attention, memory, and imagery ; and finally, there is physiology—first, ophthalmological, second, that of fatigue, and third, a part of that concerned with the central nervous system. If all works which had, through these ramifications, the remotest connexions with the central problem, were to be included, the table of references might be expanded indefinitely. But in my own experience and opinion a catalogue of this sort, by leading to an immense amount of wild-goose chasing, can be almost worse than useless, if it is not ignored. I have consulted many more references than are here mentioned, but what follows contains, with one exception, namely, numerals (which have not been dealt with experimentally in this research), only references to works which I have actually read and also found of use, for if a bibliography is to be of any service as a guide, and not a mere encyclopaedia, it must perforce be eclectic.

## APPENDIX 5 B

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